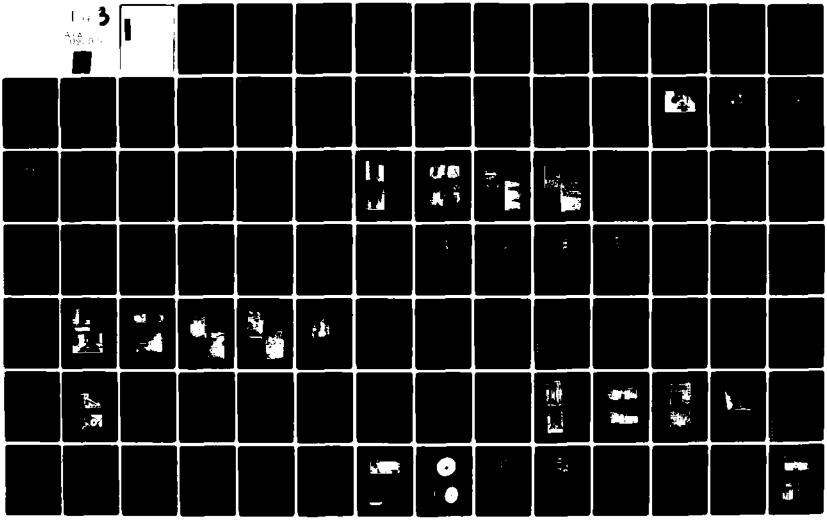
AD-A092 071 NEW MEXICO INST OF MINING AND TECHNOLOGY SOCORRO TER--ETC F/G 19/1
HIBAL PROGRAM PRELIMINARY WARHEAD-DESIGN. VOLUME I.(U)
SEP 80 N00024-79-C-5333
UNCLASSIFIED NMT/TERA-T-80-1356-U-VOL- NL



14 NMT/TERA ~~No.~~ T-80-1356-U-VOL-1

6 HIBAL PROGRAM
PRELIMINARY WARHEAD-DESIGN. V-1
Volume I.

11 15 Sep 80

PREPARED FOR

NAVAL SEA SYSTEMS COMMAND
CODE: 62R54
WASHINGTON, D. C. 20632

CONTRACT NO. N00024-79-C-5333

15

12 198

| Accession For | |
|---|---|
| NTIS GRA&I | X |
| DDC TAB | |
| Unannounced | |
| Justification PER LETTER ON FILE | |
| By | |
| Distribution/ | |
| Availability Codes | |
| Dist. | Avail and/or special |
| A | |

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY, TERA GROUP
RESEARCH AND DEVELOPMENT DIVISION
SOCORRO, NEW MEXICO 87801
15 SEPTEMBER 1980

DEPARTMENT OF THE NAVY
NAVAL SURFACE WEAPONS CENTER
DAHLGREN, VIRGINIA 22448

WHITE OAK LABORATORY
SILVER SPRING, MD. 20910
(202) 394-

DAHLGREN LABORATORY
DAHLGREN, VA 22448
(703) 663- 8715

IN REPLY REFER TO
G34:ARH:dmc
8800
OCT 03 1980

From: Commander, Naval Surface Weapons Center
To: Distribution

Subj: HIBAL Program, Preliminary Warhead Design

Encl: (1) NMT/TERA Report No. T-80-1356-U HIBAL Program Preliminary Warhead Design Volume I
(2) NMT/TERA Report No. T-80-1356-U HIBAL Program Preliminary Warhead Design Volume II (appendices)

1. The HIBAL Program was initiated in FY79 as part of the Army/Navy Area SAM Advanced Prototyping Program in NAVSEA 62R5 to develop and demonstrate new fragmentation warhead technology for defeat of bomber aircraft. The program is being conducted by the New Mexico Institute of Mining & Technology with technical support from NSWC and NWC/CL. The primary emphasis has been on obtaining fuel ingestion kills by penetrating through the large bomber fuel tanks with a relatively large fragment having good hydrodynamic penetration capability. This same fragment design has also been shown to yield improved capability against aircraft engines and on-board ordnance. The enhancement in end-game effectiveness has been found to produce not only higher probability-of-kill ($P_k$) but also a redundancy of killed components which should yield reduced susceptibility of $P_k$ to future changes in target descriptions and vulnerability models. Development of this technology is nearing completion with the final Prototype Demonstrations scheduled for early FY81.

2. In the course of this program, a considerable amount of warhead technology has been developed in the areas of liquid penetration, fuel dump capability and fragmentation control. A series of four reports is planned to document this technology to ensure maximum utilization of this data. These reports will include:

a. Fragment Drag through Liquids
b. Vulnerability Modeling Procedures for Fuel Cells
c. Preliminary Warhead Design
d. End Game Analyses

In addition, a separate report will be published documenting the Prototype Demonstration firings against running engines as well as a final report summarizing all work under this program.

G34:ANI:dmc
8800

3. Enclosures (1) and (2), Preliminary Warhead Design, are the first published in this series of reports. This report documents the application of the HIBAL fragment designs to four warhead configurations from 80 to 200 lb using both controlled fragmentation, with an opposed grooving technique, and preformed hexagonal fragments. Full scale warhead test results verify the ability to predict warhead performance and establish guidelines to successfully obtain good fireformed HIBAL fragments. These tests have also formed the basis for defining warhead characterizations for each of the HIBAL configurations.

An additional 135 lb warhead and 200 lb annular warhead are currently being tested to verify the new fragmentation control guidelines. These tests will be reported separately.

4. The four HIBAL configurations were selected to be compatible with current and projected missile systems. These designs represent Advanced Development Concepts. Application of the HIBAL technology to a specific missile system warhead design will require more extensive design tradeoffs in a number of areas including threat spectrum weighting, encounter conditions, warhead size, warhead shape, length-to-diameter ratio, and structural design.

L.M. Williams III

L.M. WILLIAMS, III
BY DIRECTION

## TABLE OF CONTENTS

TABLE OF CONTENTS (con't)



THE FOLLOWING APPENDICES MAY BE FOUND IN VOLUME II:

## 1.0 INTRODUCTION

### 1.1 BACKGROUND

This report presents the results of tests done under the Preliminary-Warhead-Design Task of the HIBAL Program. In this preliminary testing stage, basic engineering data were collected on the performance of various HIBAL-fragments, and various HIBAL-warheads. The results obtained from these tests will be used to provide warhead models for the 2nd phase of the HIBAL end-game-analysis effort. The warheads showing the greatest lethality (highest Pk) in the analysis will be selected for the design and fabrication of a set of prototype warheads for use in demonstration firings scheduled for the fall of 1980.

### 1.2 GENERAL DESIGN-GUIDELINES

The first year's effort in HIBAL consisted of a survey of aerospace contractors to identify potential HIBAL applications, creation of a HIBAL-fragment vulnerability-data-base, and a preliminary end-game analysis comparing numerous HIBAL "paper" designs. This effort resulted in a set of guidelines for the preliminary warhead designs that are discussed below.

Warhead Sizes: The aerospace-contractor survey defined four baseline HIBAL-warhead sizes; 1) 8-inch O.D., 80-lb, 2) 11-1/2- inch O.D., 135-lb, 3) 11-1/2-inch O.D., 200-lb, and 4) 19-inch O.D., 10-1/2-inch I.D., 200-lb. Designs 1, 2, and 3 are solid cylinders, while design 4 is an annulus with a 10-1/2-inch I.D. The various shrouds associated with the missiles were also identified in the survey. (NOTE: Shrouds can effect both fragment velocity and quality and thus need to be included in warhead characterization tests.)

Fragment Sizes: The HIBAL vulnerability/lethality testing was done with 700-, 1200- and 2000-grain HIBAL-fragments, and the "paper" designs for the first phase HIBAL end-game analysis included these three fragment sizes. The end-game analysis resulted in the 700-grain fragment being selected as the best choice of the above three sizes. At the January, 1980 HIBAL program review meeting it was decided to acquire data for 500- and 900-grain fragments, as well as for 700-grain fragments, to enable the second phase analysis to determine the sensitivity of $P_k$ to a choice of fragments over the range of 500- to 900-grains.

Fragment Ejection Velocities: Because the first-phase end-game analysis had determined that 5000- to 6000-ft/sec (static) ejection velocity was sufficient for the encounter conditions that were studied, 5000-ft/sec to 5500-ft/sec was set as the guideline for the preliminary warhead designs. It should be noted that the targets were heavily weighted towards manned aircraft, not cruise missiles. If the cruise missiles were heavily weighted, the ejection-velocity requirements would go up.

Fragment Shapes: The design choice was to use the maximum warhead-case-thicknesses consistent with the above ejection-velocity guidelines, because thick cases can generate "chunky" fragments that are shaped best to survive target impacts and to penetrate fuel.

Fragment Alloys: It was determined in the vulnerability testing that mild-steel fragments deform at anticipated warhead shroud and target impact conditions, and that properly heat-treated, alloy-steel fragments would better survive these impacts as demonstrated in the tests reported in Appendix 2. The preliminary warhead designs all utilized alloy steels, as discussed in the "results" section.

Warhead Style: Two separate warhead-styles were included in the preliminary designs. The first style used pre-formed, hexagonal, HIBAL fragments laid inside an outer skin. The second style used a solid case, scored inside and out with "opposed-grooves" to produce "fireformed fragments" of a controlled shape and size. The preformed fragments have adequate fuel cell penetration capability, as demonstrated in liquid drag tests. The solid-case design associated with the fireformed fragments has some potential advantages. For example, the elimination of a need for inner and outer skins associated with preformed fragment cases permits fireformed fragments to be thicker, therefore to have smaller surface dimensions to give the same weight fragment, thus providing a more compact fragment and a better fuel penetrator. Opposed grooves were used because existing Pearson-type grooving technology or liner technology does not produce fragments that have good drag characteristics due to the fragments shape and roughness. Opposed grooves showed feasibility for achieving fireformed fragments having acceptable drag characteristics. At this point in HIBAL, both styles are considered to be design candidates.

Preliminary Designs: The design guidelines recommended after the January 1980 HIBAL Program Review resulted in four warhead configurations being defined for full-scale characterization and engineering tests:

A. Solid 80-lb with 500-grain (fireformed) and 700-grain (pre- and fireformed) fragments.

B. Solid 135-lb with 700-grain (pre- and fireformed) and 900-grain (fireformed) fragments.

C. Solid 200-lb with 700-grain (pre- and fireformed) and 900-grain (fireformed) fragments.

D. Annular 200-lb with 700-grain (pre- and fireformed) and 900-grain (fireformed) fragments.

The devices actually designed and tested differed somewhat from the above recommendations in that all three fragment sizes (500-, 700- and 900-grain) were included in all four warhead sizes. This was possible because of the large amount of data surface available in all the warhead sizes, and was deemed desirable because it would provide models of all three fragment sizes for each of the four warheads in the second-phase end-game analysis.

## 1.3 OBJECTIVES

The basic objectives of the test program included:

1. Generation of data on fragment polar ejection-angles, velocities, shapes, and weights for each of the preliminary warhead designs.

2. Utilization of the generated data to:

   A. Recommend any warhead design alterations which may be required (for example, if a particular shroud configuration shattered the fragments, a design alteration would be required).

   B. Formulate warhead characterization models to be used in the second phase end game analysis.

## 1.4 APPROACH

### 1.4.1 WARHEAD DESIGNS

#### 1.4.1.1 PREFORMED FRAGMENT WARHEADS

Warhead case thickness and length dimensions for the various warhead diameter choices were guided by the weight limitations and by the velocity constraints imposed, using the prediction methodology presented in Appendix 3. Only an outside skin was used, with hoops provided at each end to provide rigidity. The inside skin that would be required in a final warhead design was not considered necessary at this level of the testing effort, because the structural strength was not needed, and the effect of the thin skin (0.010-inch thick) on performance was deemed negligible. The fragments were arranged on the inside of the skin and potted in laminac. Hand-packed C-4 explosive was used in all the tests.

#### 1.4.1.2 FIREFORMED FRAGMENT WARHEADS

Warhead case thickness and length dimensions for the various warhead diameter choices were guided by the weight limitations and by the velocity constraints imposed, using the prediction methodology presented in Appendix III. The approach used to design the opposed-grooves was to use the shallowest grooves which would fireform fragments of the desired shape and weight. Shallow grooves would leave the warhead case strongest, would remove the least metal and would permit faster and easier fabrication of the warhead case. Hand-packed C-4 explosive was used in all the tests. See section 2.1.1 for definitions of the terms used in discussing fireformed warheads, and also see Figure 1.

### 1.4.2 TESTING

Witness sheets were used to record fragment hit locations for the measurement of polar ejection angles and to measure fragment velocities using high-speed cameras. Celotex was used to recover fragments so as to measure fragment weights and to provide a record of the fragment shapes attained.

Prior to testing the first fireformed warhead a series of mat tests were made to generate some design data for the opposed groove technique. The mat tests were much cheaper and faster than tests of full scale warheads would have been. The design of the first warhead was based on the results of these mat tests.

# 2.0 RESULTS

## 2.1 DETAILED WARHEAD TEST RESULTS

### 2.1.1 SUMMARY OF WARHEAD TEST CONDITIONS, EXPLANATION OF PAGE NUMBERING SYSTEM, AND DEFINITIONS OF TERMS USED IN RESULTS

Table 2.1.1, presents a summary of the physical characteristics of the warheads in each of the tests. The tests are presented in chronological order, which is the sequence shown in Table 2.1.1. The page numbers and figure numbers used in this section are tied to the NMT test number. For example, the first test conducted in the series was NMT test number QN0225A0. Therefore the page numbers and figure numbers associated with this test are prefaced by 225- (i.e., 225-1, 225-2, etc.). The following pages and figures are numbered similarly.

Definitions of certain terms used in the discussion of the designs of fireformed warheads are presented below. Refer to Figure 1.

1. Longitudinal Grooves

   Grooves parallel to the warhead axis.

2. Circumferential Grooves

   Grooves perpendicular to the warhead axis.

3. Inside Grooves

   Grooves on the inside of the warhead case.

4. Outside Grooves

   Grooves on the outside of the warhead case.

5. Groove Angle

   Interior (apex) angle of the groove.

6. Longitudinal-Groove Spacing

   Circumferential distance between the longitudinal grooves.

7. Circumferential-Groove Spacing

   Longitudinal distance between the circumferential grooves.

8. Metal Remaining Between Grooves

   The thickness of metal remaining between the apexes of the inside and outside, opposed grooves.

In all tests, the warhead case was of heat treated alloy, and Table 2.1.2 summarizes the heat-treatment procedures.

Appendix III presents the methodology used to predict fragment ejection velocities and polar angles.

TABLE 2.1.2

SUMMARY OF HEAT TREATMENT PROCEDURES
USED IN EACH OF THE WARHEAD TESTS

| TEST NO. | WARHEAD CASE MATERIAL | HEAT TREATMENT PROCEDURE | MEASURED RC HARDNESS |
|---|---|---|---|
| QN0225A0 | 4130 | Quenched from 1575 degrees in water, tempered at 800 degrees | 43 |
| QN0311A0 | 4140 | Quenched from 1550 degrees in oil, tempered at 800 degrees | 40-42 |
| QN0319A0 | 4130 | Quenched from 1575 degrees in water, tempered at 800 degrees | 42 |
| QN0328A0 | 4140 | Quenched from 1550 degrees in oil, tempered at 800 degrees | 37-42 |
| QN0409A0 | 4130 | Quenched from 1575 degrees in oil, tempered at 800 degrees | 42 |
| QN0429A0 | 4140 (Fireformed) | Quenched from 1550 degrees in oil, tempered at 800 degrees | 37-42 |
| | 4130 (Preformed) | Quenched from 1575 degrees in oil, tempered at 800 degrees | 44-47 |
| QN0514A0 | SSS-100 (Fireformed) | Quenched from 1650 degrees in oil, tempered at 800 degrees | 42 |
| | HY-80 (Fireformed) | Quenched from 1640 degrees in oil, tempered at 800 degrees | 40-43 |
| | 4130 (Preformed) | Quenched from 1575 degrees in oil, tempered at 800 degrees | 40-42 |

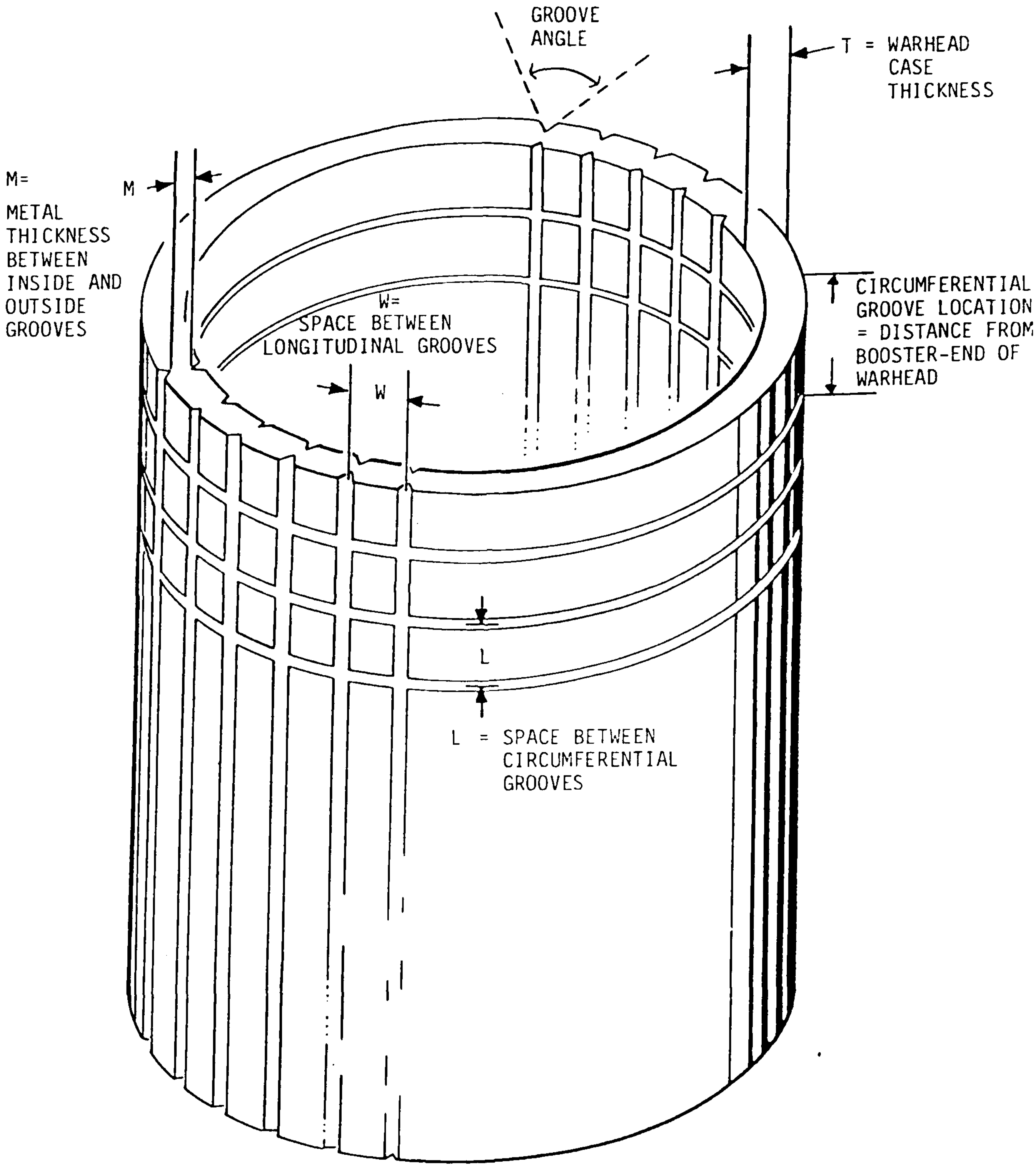
NOTE: All temperatures refer to the Fahrenheit scale.

TABLE 2.1.1

SUMMARY TABLE OF WARHEAD TEST CONDITIONS

| | TEST NO. QNO---AO | WARHEAD ** SIZE | | | CASE** THICK-NESS | WARHEAD WEIGHT (lbs) | SHROUD DESCRIPTION | | | | | | FRAG TYPE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | INNER PORTION | | CENTER PORTION | | OUTER PORTION | | | |
| | | O.D. | I.D. | L | | | THICK-NESS** | MATERIAL | THICK-NESS** | MATERIAL | THICK-NESS** | MATERIAL | PRE | FIRE |
| 1 | 225 | 8.0 | 2.0 | 15.0 | 0.438 | 80 | 1 | Urethane Foam | NONE | | 0.050 | Titanium | | X |
| 2 | 311 | 11.5 | 2.9 | 14.0 | 0.500 | 135 | 1 | Urethane Foam | 0.020 | Mild Steel | 0.030 | Mild Steel | | X |
| 3 | 319 | 8.0 | 2.0 | 15.2 | 0.445* | 80 | 1 | Urethane Foam | NONE | | 0.050 | Titanium | X | |
| 4 | 328 | 11.5 | 2.9 | 18.4 | 0.563 | 200 | 1 | Urethane Foam | 0.020 | Mild Steel | 0.030 | Mild Steel | | X |
| 5 | 409 | 19.0 | 10.5 | 12.5 | 0.500 | 200 | 1 | Urethane Foam | NONE | | 0.080<br>0.020 | Titanium<br>Titanium | X | <br>X |
| 6 | 429 | 11.5 | 2.9 | 18.4 | 0.563 | 200 | 1 | Urethane Foam | 0.020 | Mild Steel | 0.030 | Mild Steel | X | X |
| 7 | 514 | 11.5 | 2.9 | 14.0 | 0.500 | 135 | 1 | Urethane Foam | 0.020 | Mild Steel | 0.030 | Mild Steel | X | X |

* Total thickness of skin and pre-formed fragment
** NOTE: All dimensions are given in inches.




OPPOSED V-GROOVES FOR FIREFORMING FRAGMENTS



FIGURE 1

DETAILS OF WARHEAD TEST DEVICES, ARENAS,
AND RESULTS

TEST QN0225A0

8-INCH, 80-LB, FIREFORMED-FRAGMENT WARHEAD

## 2.1.2 TEST 1, QN0225A0

### 2.1.2.1 DESIGN SUMMARY AND RATIONALE

The basic design characteristics of the warhead (Figure 225-1) fired in Test 1 were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 8-inch |
| INSIDE DIAMETER: | 2-inch |
| LENGTH: | 15-inch |
| CASE THICKNESS: | 0.438-inch |
| CASE MATERIAL: | SAE 4130 (RC-42) |
| FRAGMENT TYPE: | FIREFORMED |
| WARHEAD WEIGHT: | 80-lb |
| SHROUD: | 0.050-inch titanium, with 1-inch urethane foam insulation |

The 2-inch inside diameter was used because it is a typical cavity-size (for safe-and-arm requirements) in warheads of this size-range. The case thickness and length combination was designed to provide fragment velocities between 5000 and 5500-ft/sec (after passing through the missile shroud) and, also, to maintain the 80-lb weight limitation. SAE 4130 alloy was used for the fragment case based on the design guidelines generated by the results of the mat tests (presented in Appendix-I). The shroud design, Figure 225-2, was based on information provided by missile manufacturers.

The fragment case was grooved circumferentially to provide for 15 rows of equal-length fragments, each 0.933 -inch long (i.e. 0.933-inch spacing between grooves). The spacing between longitudinal grooves was varied to determine if the spacing significantly affected fragment quality. The spacings tested were 0.75-, 0.875-, 1.0- and 1.25-inch. (NOTE: The weight of the fragments, if ejected with no loss of weight during the fireforming process, would be 550-, 640-, 740- and 840-grains, for the respective spacings. These weights were designed to be on the heavy side with the expectation that fireforming losses would bring the fragments down to their appropriate nominal weights.

The interior angle of all the grooves in this warhead (and all the following warheads) was 37°. This angle was used because the attempt to machine smaller angles resulted in excessive shaper-tool breakage (and in significantly increased fabrication time).

From the mat firings (Appendix 1) for this warhead case-thickness, the depth of the longitudinal grooves should be about 0.095-inch deep (inside and outside, or a total depth of 0.19-inch) and, near the booster-end, the depths of the circumferential grooves should be 0.095-inch (inside and outside, or a total depth of 0.19-inch) and, near the non-booster-end 0.130-inch (inside and outside, or a total depth of 0.26-inch). Variations around the above groove depths were made in this test device, to increase the likelihood of encompassing groove depths that would produce good results.

The longitudinal groove depths were:

| INSIDE GROOVE DEPTH (inch) | OUTSIDE GROOVE DEPTH (inch) | METAL REMAINING BETWEEN GROOVES (inch) |
|---|---|---|
| 0.090 | 0.060 | 0.285 |
| 0.090 | 0.090 | 0.258 |
| 0.100 | 0.080 | 0.258 |
| 0.110 | 0.080 | 0.248 |
| 0.100 | 0.100 | 0.238 |
| 0.110 | 0.110 | 0.218 |
| 0.120 | 0.120 | 0.198 |

The circumferential grooves were of variable depth around the circumference of the warhead but, at a given circumferential location, the inside-groove depth equalled the outside-groove depth.

| GROOVE NUMBER | MINIMUM GROOVE DEPTH (inch) | MAXIMUM METAL REMAINING BETWEEN GROOVES (inch) | MAXIMUM GROOVE DEPTH (inch) | MINIMUM METAL REMAINING BETWEEN GROOVES (inch) |
|---|---|---|---|---|
| 1, 2, 3, 4, (booster end) | 0.080 | 0.278 | 0.125 | 0.188 |
| 5, 6, 7, 8 | 0.090 | 0.258 | 0.135 | 0.168 |
| 9, 10, 11, 12 | 0.100 | 0.238 | 0.145 | 0.148 |
| 13, 14, 15, 16 | 0.110 | 0.218 | 0.155 | 0.128 |

Note (in Figure 225-1) that the location of deepest longitudinal grooves corresponded (approximately) to the location of the deepest circumferential grooves, and the location of the shallowest longitudinal grooves corresponded to the location of the shallowest circumferential grooves.

### 2.1.2.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENA

The objectives of this test included recovering a sample of fragments from each opposed-groove design-choice, and characterizing the warhead fragment-pattern in terms of fragment polar-ejection angle and of fragment velocity. Celotex was used to recover the fragments, and steel witness sheets were used to record fragment pattern and as flash screens for velocity measurements. A plan view of the test arena is shown in Figure 225-7, and photographs of the arena are shown in Figures 225-12 and 225-13.

2.1.2.3 DESCRIPTION OF TEST RESULTS

A. Fragment Quality

Judgement of the success or failure of each opposed-groove design is based on two factors, the shape of the fragment and the weight of the fragment. The shape of the fragment is important because, if not correct, fragment individual weights vary and fragment survivability during impact with the target is decreased.

1. Longitudinal Grooves

The quality of the fragment breakout along the longitudinal grooves is given in relative terms, in the table below. The term "borrowed" means that the fragments did not breakout properly, some fragments having some of the steel attached to them that should have remained with neighboring fragments.

| INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING BETWEEN GROOVES* (inch) | BREAKOUT QUALITY |
|---|---|---|---|
| 0.090 | 0.060 | 0.288 | Poor - all fragments "borrowed" |
| 0.090 | 0.090 | 0.258 | Poor - almost all fragments "borrowed" |
| 0.100 | 0.080 | 0.258 | Poor - almost all fragments "borrowed" |
| 0.110 | 0.080 | 0.248 | Fair - 50% of fragments "borrowed" |
| 0.100 | 0.100 | 0.238 | Good - 20% of fragments "borrowed" |
| 0.110 | 0.110 | 0.218 | Very Good - 10% of fragments "borrowed" |
| 0.120 | 0.120 | 0.198 | Excellent - no fragment borrowing |

Fragments of the desired quality are illustrated in Figure 225-4, and the poorest-quality fragments are illustrated in Figure 225-5.

* The metal remaining between groove apexes was not shown to be a significant parameter until much of the test program was completed. Results are presented in terms of this parameter, to explain why certain groove designs work, and others do not.

2. Circumferential Grooves

The fragment breakout along the circumferential grooves was excellent, except for two minor faults. These were, (1) occasional fragment doubles or lengthwise pairings occurred (Figure 225-5) and, (2) when the internal circumferential grooves exceeded 0.120-inch depth (Figure 225-6), the non-booster-end inside corners of the fragment broke off.

CIRCUMSTANCES WHERE FRAGMENT DOUBLES OCCURRED

| FRAGMENT ROW | FRAGMENT DOUBLES | INSIDE GROOVE DEPTH (inch) | OUTSIDE GROOVE DEPTH (inch) | METAL REMAINING BETWEEN GROOVES* (inch) |
|---|---|---|---|---|
| 1, 2 | NONE | ----- | ----- | ----- |
| 3, 4 | YES | 0.118 | 0.118 | 0.202 |
| 5, 6, 7, 8 | YES | 0.113 | 0.113 | 0.212 |
| 9, 10, 11, 12 | YES | 0.100 | 0.110 | 0.238 |
| 13, 14, 15, 16 | NONE | ----- | ----- | ----- |

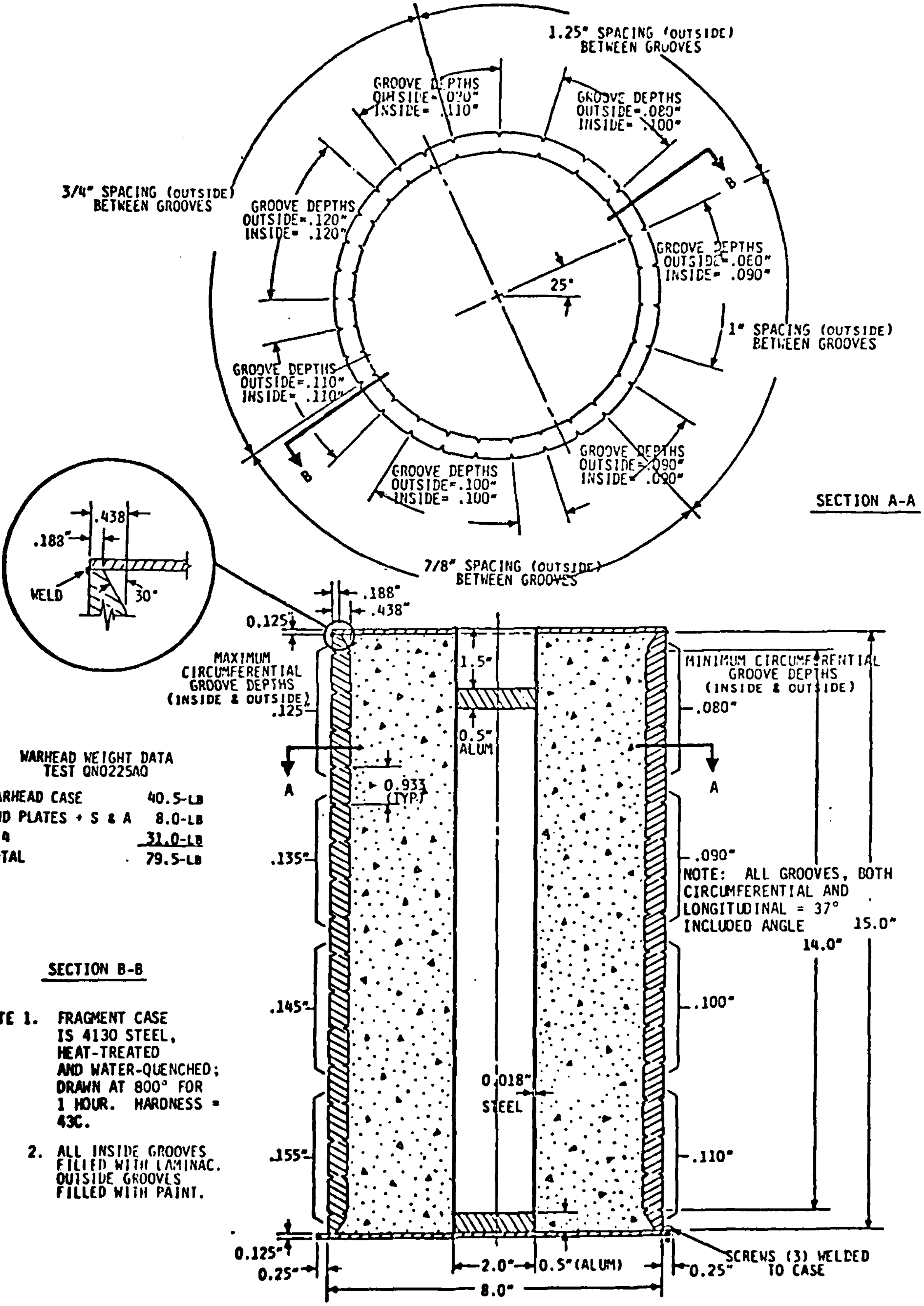
Fragment weights are presented in two tables for each longitudinal groove spacing, one which lists the fragments which could be identified by row origin, and one which lists all recovered fragments. The tables are located on pages 225-20 through 225-25.

B. Fragment Pattern and Velocity

Fragment patterns from the witness sheets are plotted in Figures 225-8 and 225-9. Photos of the witness sheets appear in Figures 225-14 and 225-15. Coordinates of the fragment hit-locations are presented in Figure 225-10. The fragment velocity and polar-ejection-angle characterization are summarized in Figure 225-11.

C. Conclusions

There is no need for further 8-inch diameter, 80-lb, fireformed warhead tests. The recovered fragment shapes and weights were satisfactory, and the pattern and velocity data were adequate to formulate warhead characterization models for the second phase end-game analysis.




**WARHEAD WEIGHT DATA**
**TEST QN0225A0**

| | |
|---|---|
| WARHEAD CASE | 40.5-LB |
| END PLATES + S & A | 8.0-LB |
| C-4 | 31.0-LB |
| TOTAL | 79.5-LB |

NOTE 1. FRAGMENT CASE IS 4130 STEEL, HEAT-TREATED AND WATER-QUENCHED; DRAWN AT 800° FOR 1 HOUR. HARDNESS = 43C.

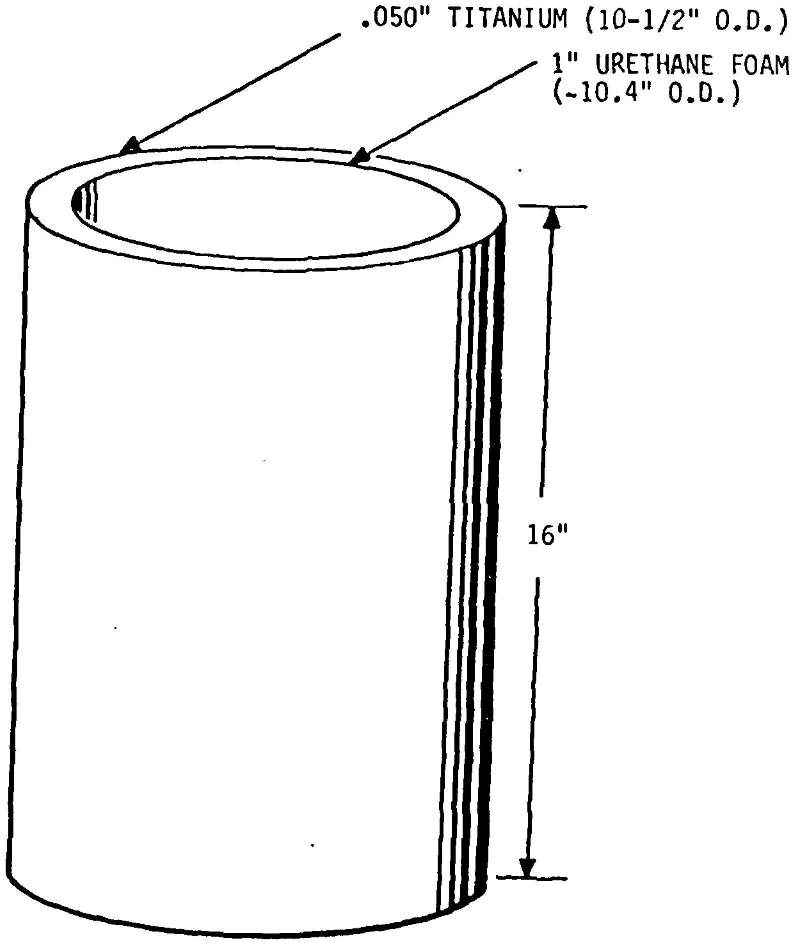
2. ALL INSIDE GROOVES FILLED WITH LAMINAC. OUTSIDE GROOVES FILLED WITH PAINT.

TEST QN0225A0

WARHEAD DESIGN



FIGURE 225-1

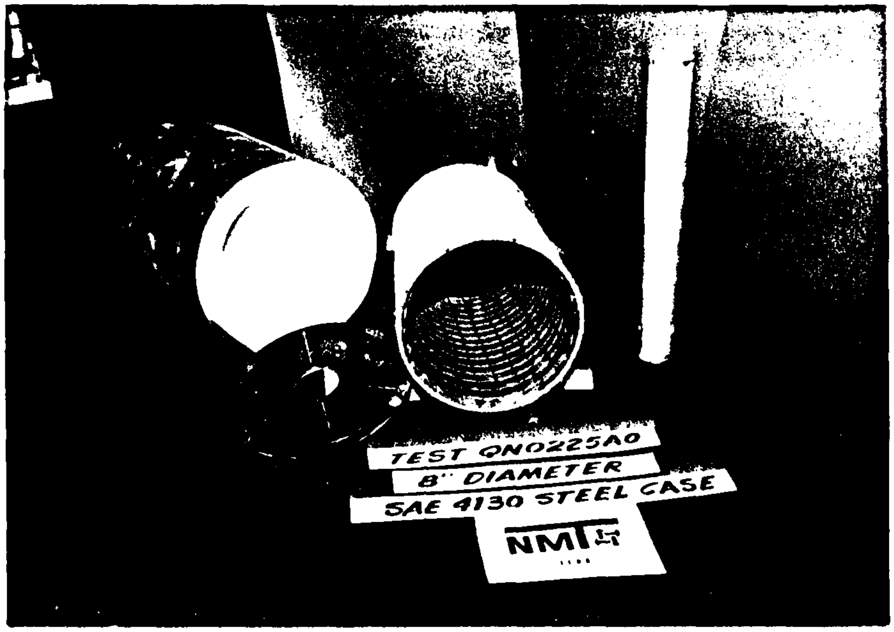



SHROUD FOR 8" O.D., 80-LB WARHEAD

TEST QN0225A0



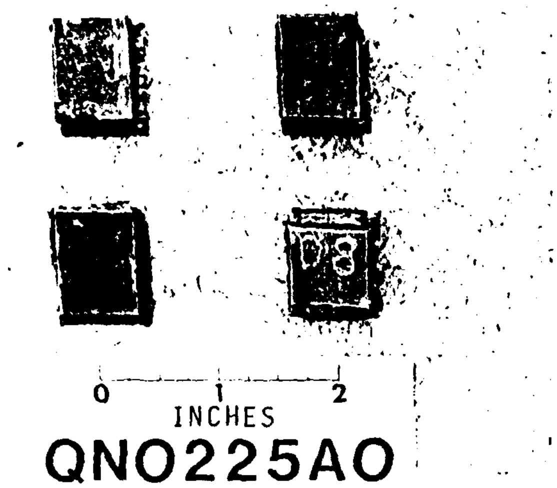
FIGURE 225-2

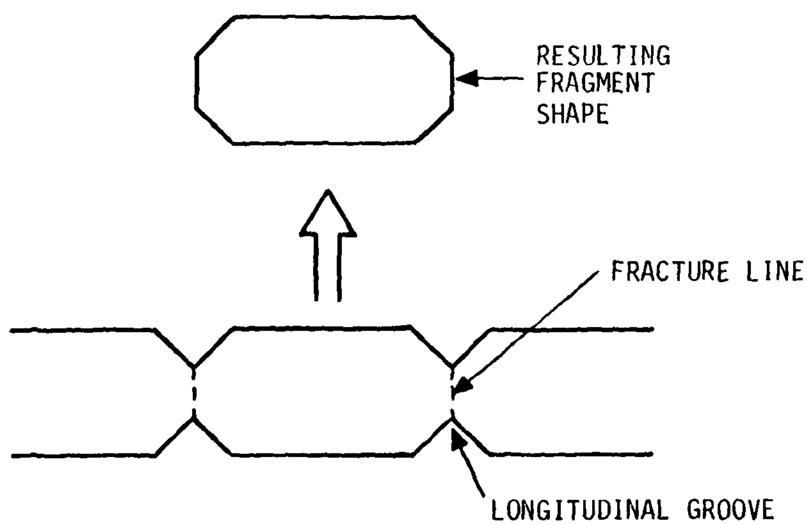



WARHEAD COMPONENTS PRIOR TO ASSEMBLY AND LOADING



FIGURE 225-3

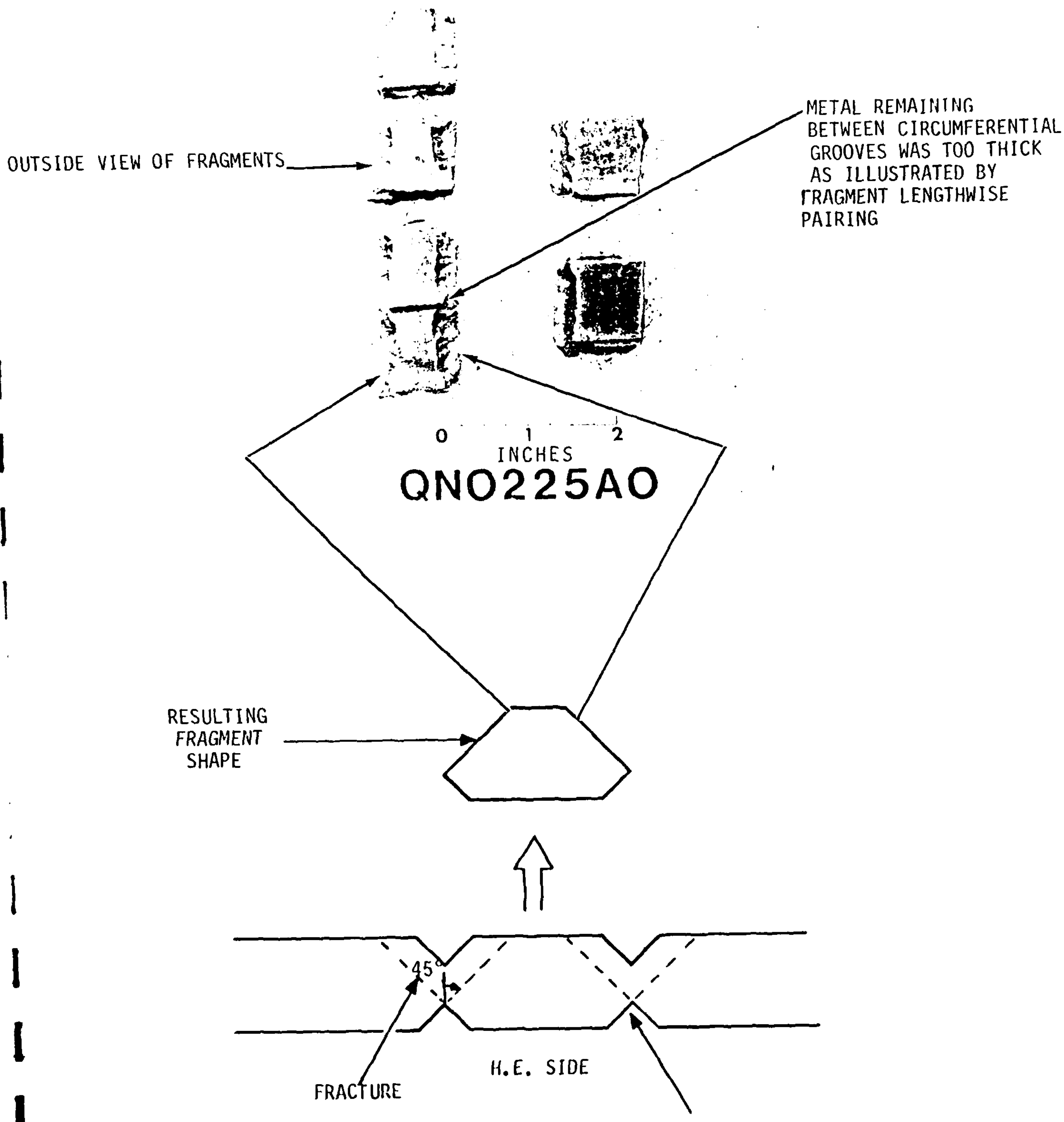



H.E. SIDE

FRAGMENT SHAPE RESULTING WHEN THE METAL REMAINING BETWEEN LONGITUDINAL INSIDE AND OUTSIDE GROOVES IS BETWEEN 0.200" AND 0.240"

EXAMPLE FRAGMENTS FROM TEST QNO225AO




REDUCED-WEIGHT FRAGMENTS RESULTING WHEN METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.280" OR MORE

EXAMPLE FRAGMENTS FROM TEST QN0225A0

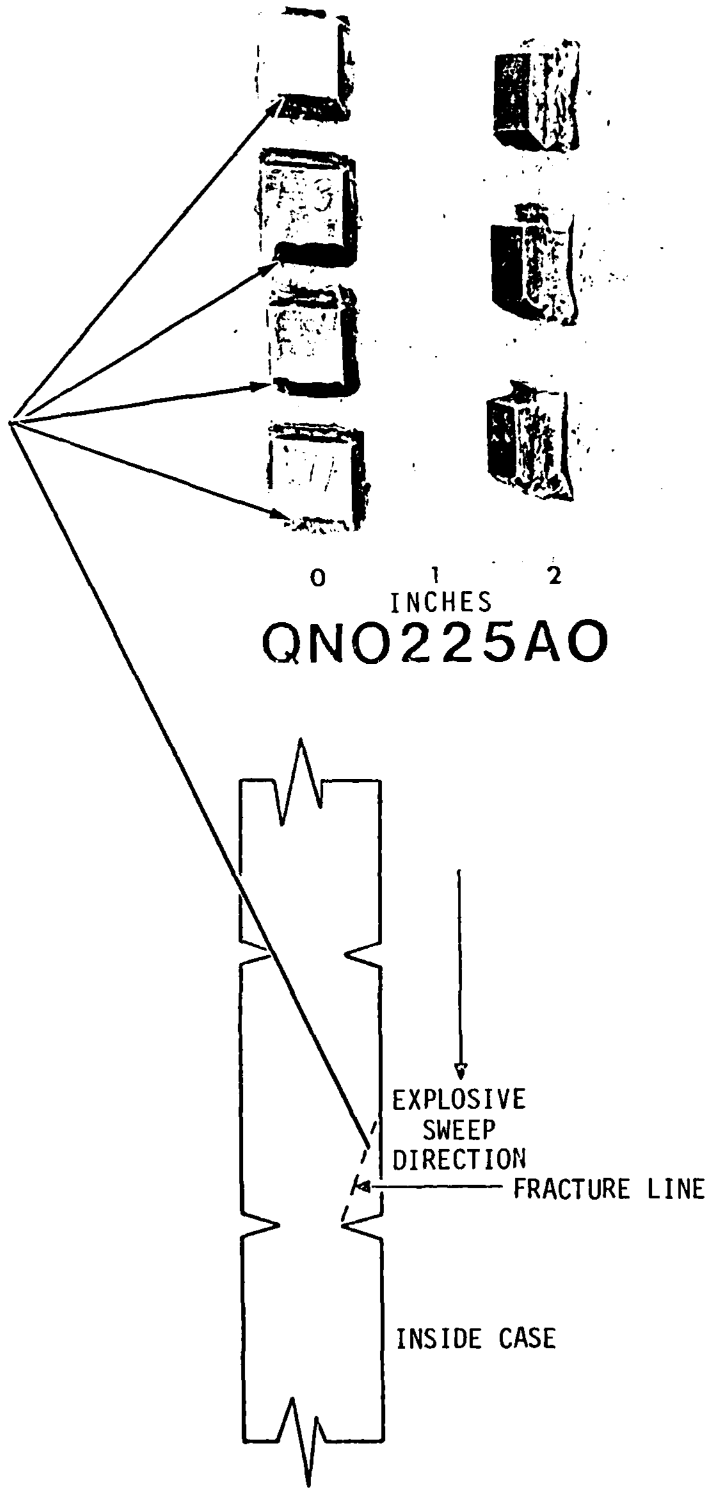
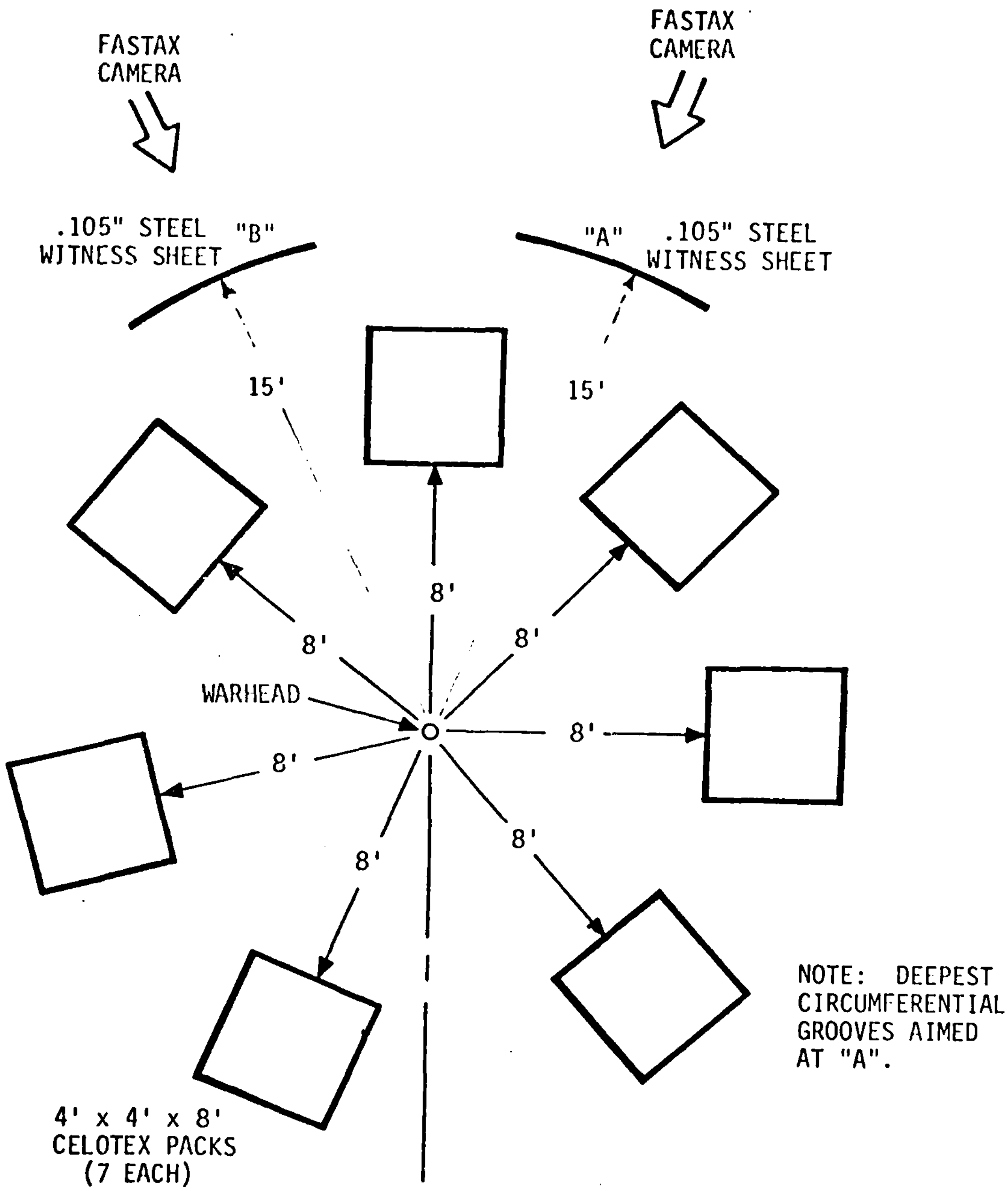



ILLUSTRATION SHOWING THE FRACTURE WHICH OCCURRED WHEN THE
INSIDE CIRCUMFERENTIAL GROOVES EXCEEDED 0.120" DEPTH

EXAMPLE FRAGMENTS FROM TEST QN0225A0

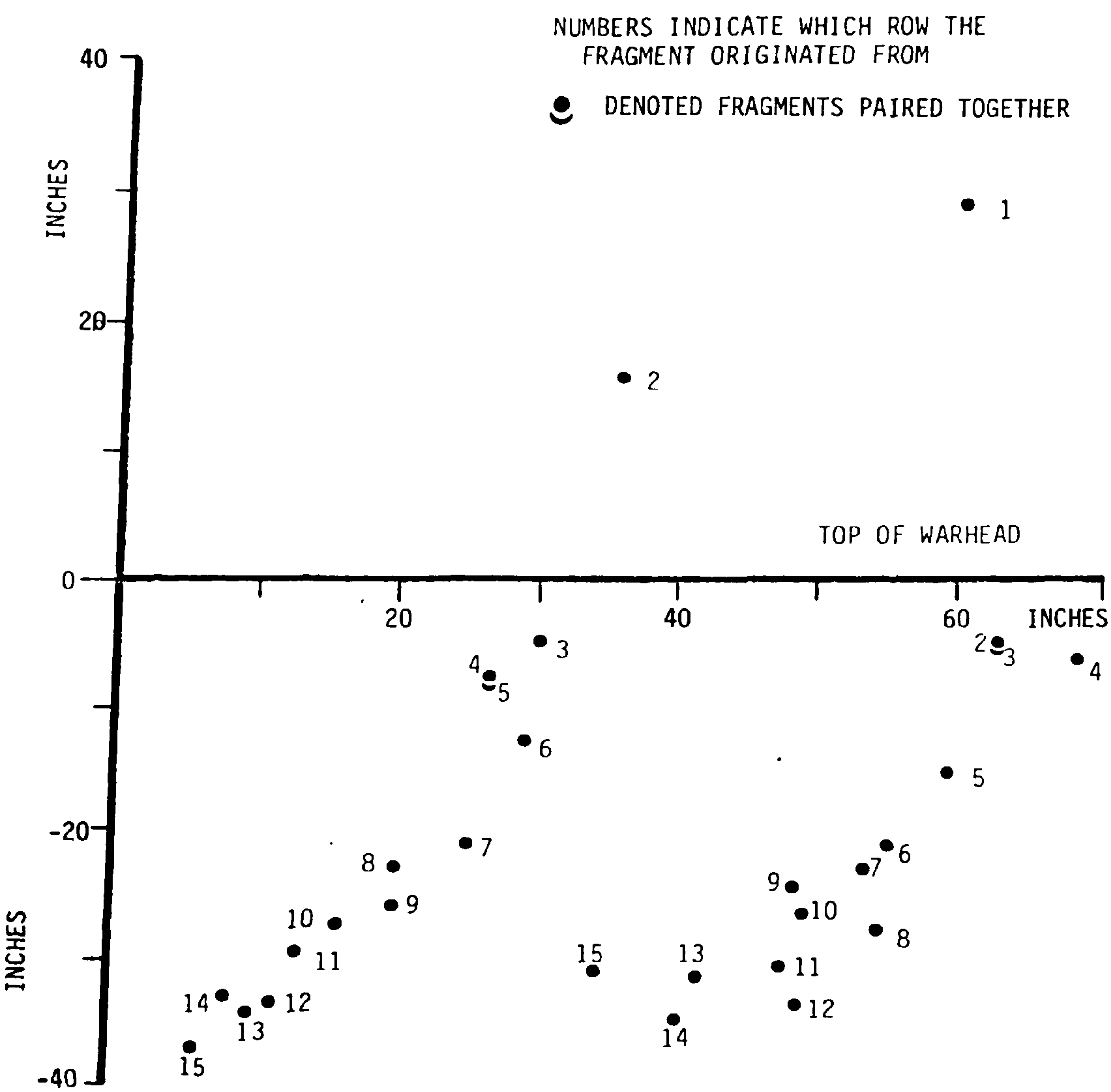



TEST QN0225A0

8" O.D., 80-LB, FIRE-FORMED HIBAL FRAGMENT WARHEAD



FIGURE 225-7

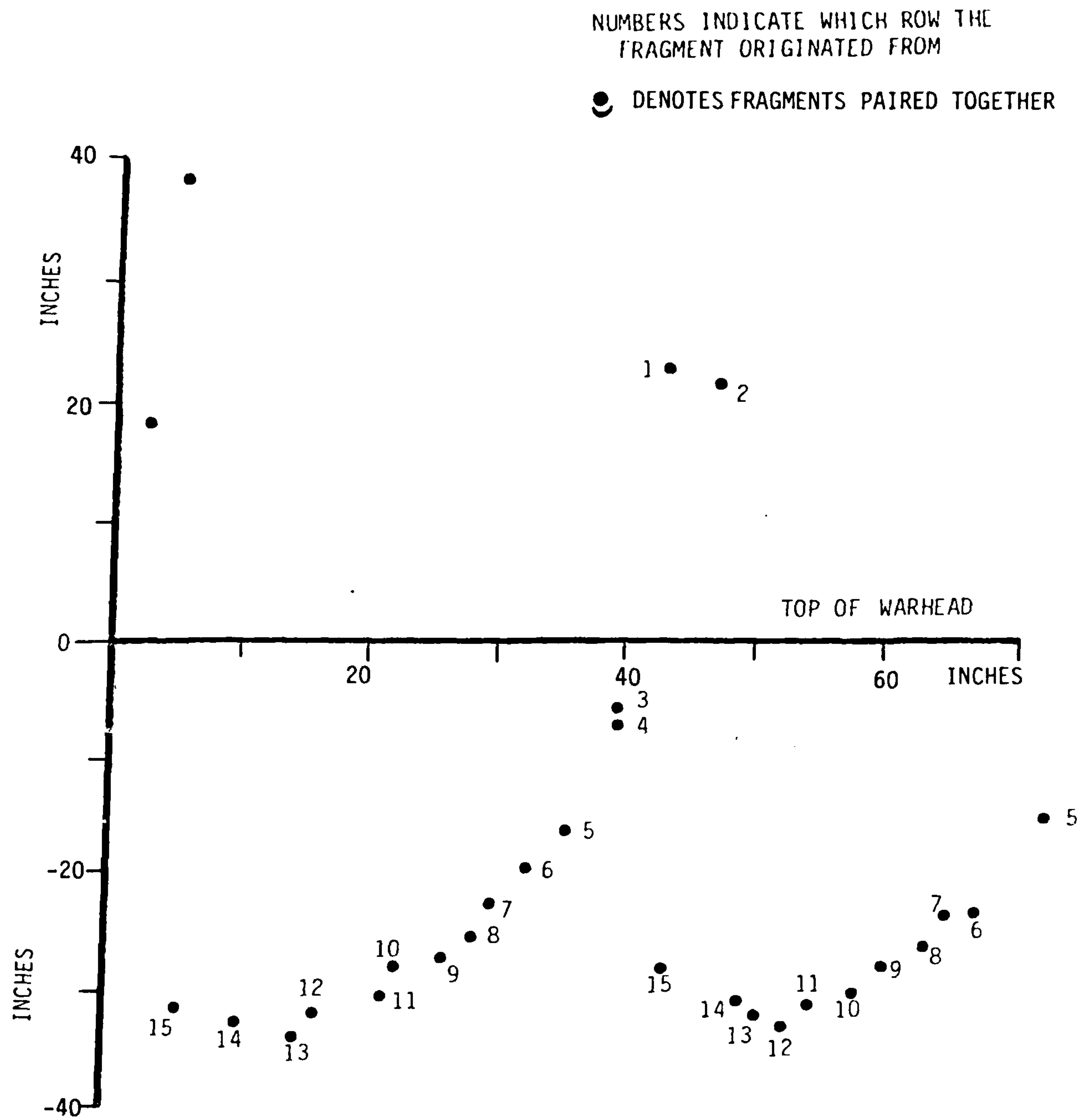



FRAGMENT PATTERN ON WITNESS SHEET "A"
AS VIEWED FROM EXIT SIDE

TEST ONO225AO



FIGURE 225-8




FRAGMENT PATTERN ON WITNESS SHEET "C" AS VIEWED FROM FRAGMENT EXIT SIDE

TEST QNO225AO



FIGURE 225-9

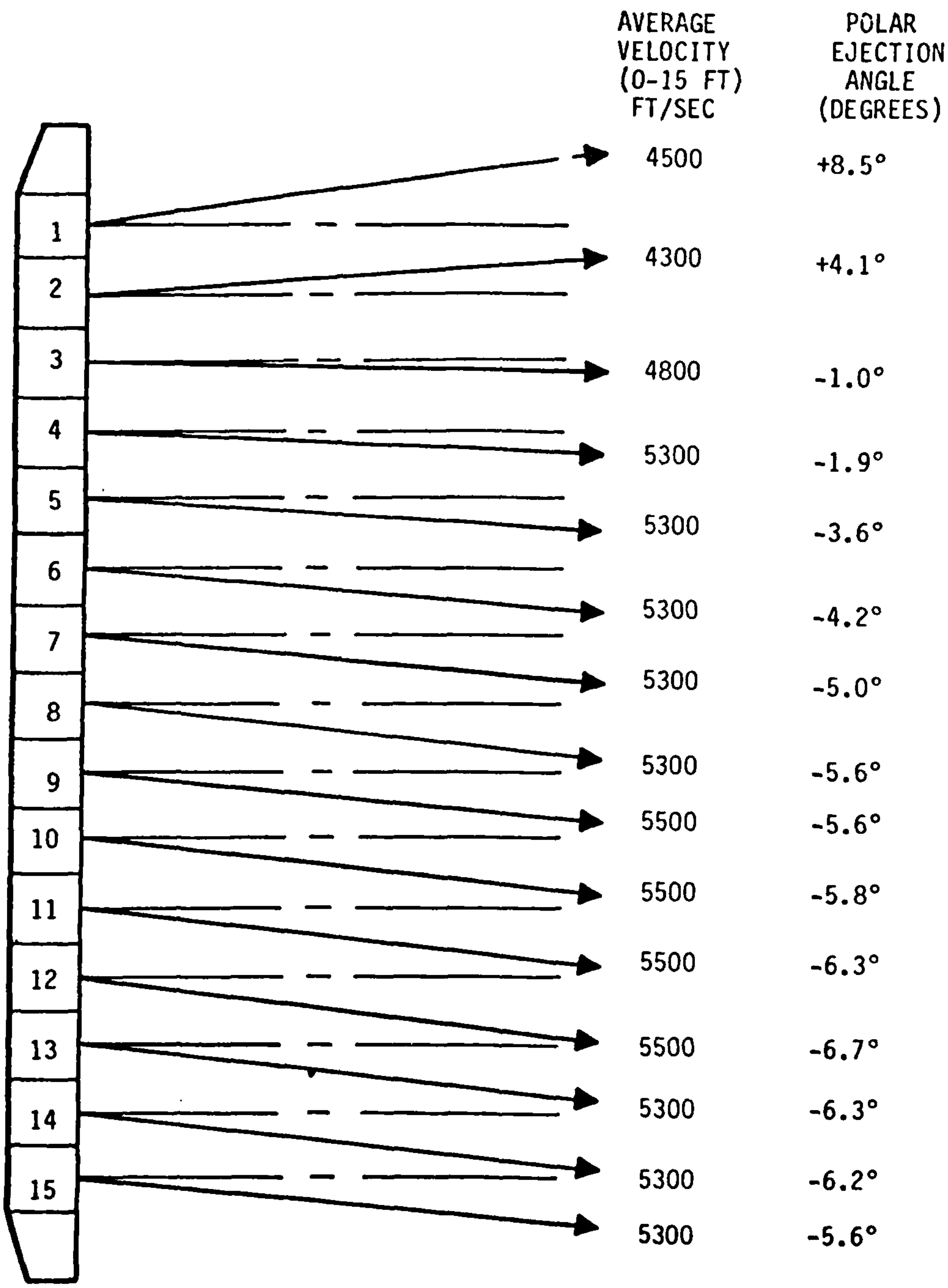
TEST QN0225A0

COORDINATES* OF FRAGMENT HIT LOCATIONS (INCHES) ON THE WITNESS SHEETS AT 15-FT RADIUS

| FRAGMENT ROW NUMBER | WITNESS SHEET "A" | | | | WITNESS SHEET "C" | | | |
|---|---|---|---|---|---|---|---|---|
| | COLUMN 1 | | COLUMN 2 | | COLUMN 1 | | COLUMN 2 | |
| | HORIZ. | VERT. | HORIZ. | VERT. | HORIZ. | VERT. | HORIZ. | VERT. |
| 1 | 59 | +28 | - | - | 43 | +22 | - | - |
| 2 | 35 | +15 | 63 | - 6 | 46 | +21 | - | - |
| 3 | 30 | - 5 | 63 | - 6 | 39 | - 7** | - | - |
| 4 | 26 | - 8** | 68 | - 7 | 39 | - 6** | - | - |
| 5 | 26 | - 9** | 59 | -15 | 35 | -16 | 72 | -16 |
| 6 | 29 | -13 | 55 | -21 | 32 | -19 | 67 | -23 |
| 7 | 25 | -21 | 54 | -23 | 30 | -22 | 60 | -24 |
| 8 | 20 | -22 | 55 | -28 | 28 | -25 | 63 | -26 |
| 9 | 20 | -26 | 48 | -24 | 26 | -27 | 60 | -28 |
| 10 | 17 | -27 | 49 | -26 | 22 | -28 | 58 | -30 |
| 11 | 13 | -29 | 48 | -31 | 21 | -30 | 54 | -31 |
| 12 | 12 | -33 | 49 | -33 | 16 | -31 | 52 | -33 |
| 13 | 10 | -33 | 42 | -31 | 15 | -33 | 50 | -32 |
| 14 | 9 | -33 | 41 | -35 | 10 | -32 | 49 | -31 |
| 15 | 6 | -37 | 34 | -31 | 6 | -31 | 43 | -28 |

* Vertical measurements are measured from the top of the warhead aimline; horizontal measurements are measured from the left hand side of the witness sheet as viewed from the fragment exit side.

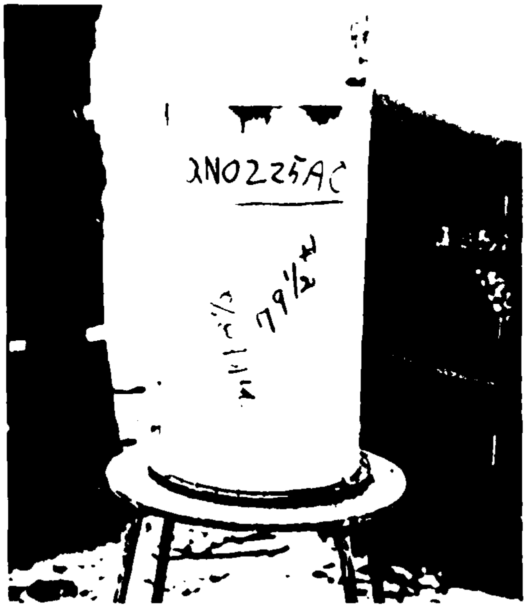
** Fragments paired together.



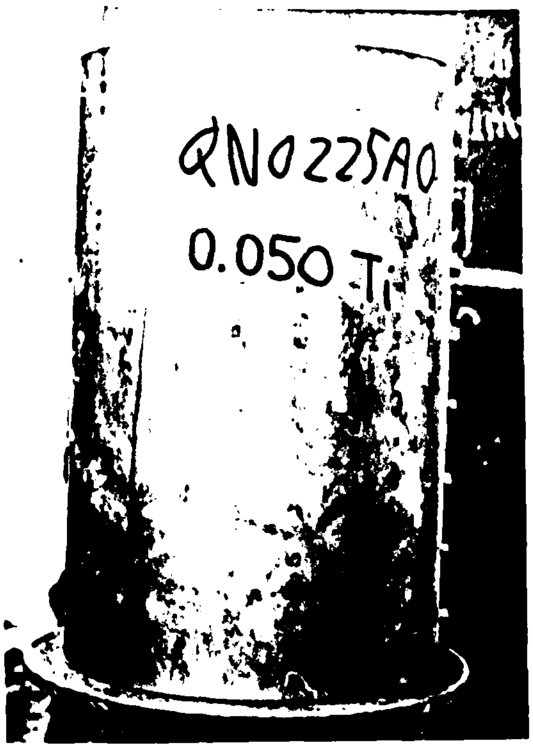

FRAGMENT VELOCITY AND POLAR ANGLE CHARACTERIZATION FOR AN 8" O.D., 80-LB, FIRE-FORMED HIBAL WARHEAD, BASED ON DATA FROM TEST QN0225A0



FIGURE 225-11



VIEW OF WARHEAD IN PLACE IN TEST ARENA WITH SHROUD REMOVED

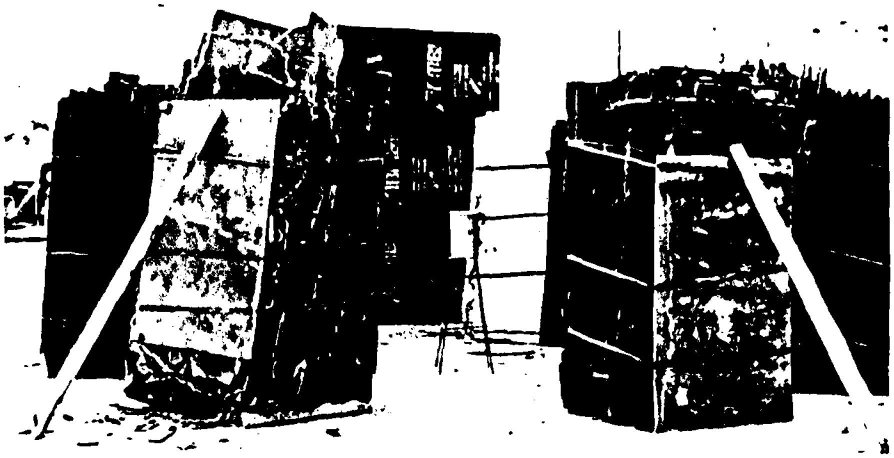



WARHEAD IN TEST ARENA WITH SHROUD INSTALLED



FIGURE 225-12

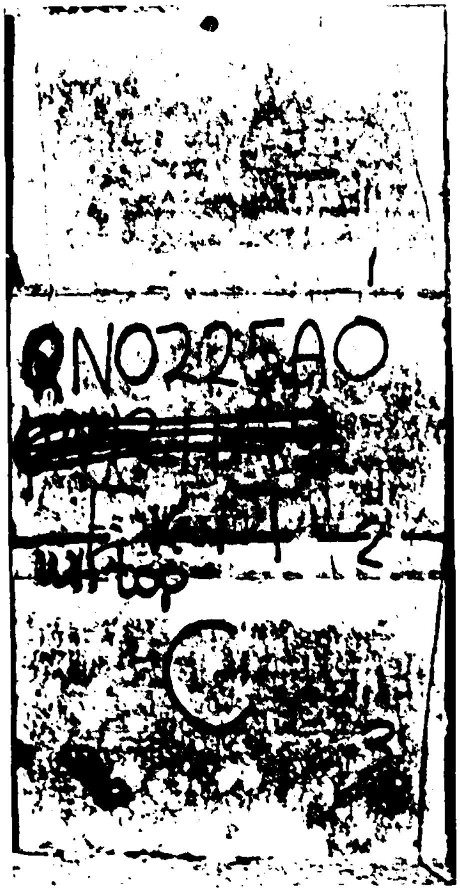
TEST: 0N0225A0



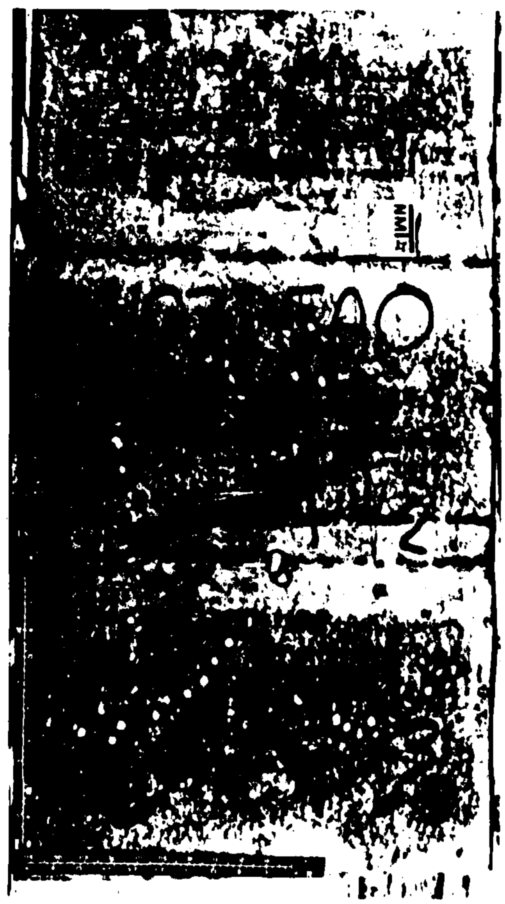
VIEWS OF THE TEST ARENA BEFORE DETONATION




FIGURE 225-13



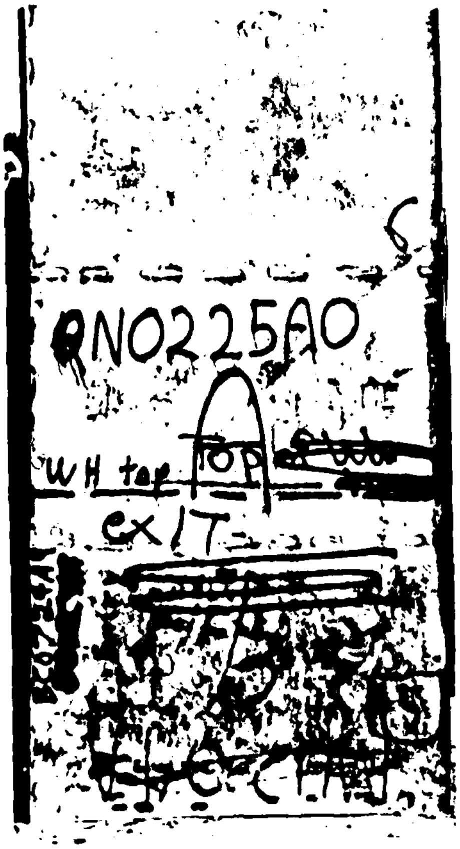

WITNESS SHEET "C" BEFORE TEST;
EXIT SIDE; 15' RADIUS



WITNESS SHEET "C" AFTER TEST;
EXIT SIDE; 15' RADIUS



FIGURE 225-14




WITNESS SHEET "A" BEFORE TEST;
EXIT SIDE; 15' RADIUS


WITNESS SHEET "A" AFTER TEST;
EXIT SIDE; 15' RADIUS



FIGURE 225-15

# WEIGHTS OF RECOVERED FRAGMENTS WHICH WERE IDENTIFIABLE BY FRAGMENT ROW
## TEST QN0225A0

| GROOVE-SPACING (circumferential) | | 1-1/8-inch SPACING | | | | 1.0-inch SPACING | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTH INSIDE | | 0.100-inch | | | | 0.090-inch | | | | 0.090-inch | | | |
| LONGITUDINAL GROOVE DEPTH OUTSIDE | | 0.080-inch | | | | 0.060-inch | | | | 0.090-inch | | | |
| | FRAGMENT ROW | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT : THEORETICAL WEIGHT |
| BOOSTER END | 1 | .090 | 839 | 1060[1] | 1.36 | .080 | 749 | --- | --- | .096 | 742 | --- | --- |
| | 2 | .090 | 839 | 788 | .94 | .080 | 749 | --- | --- | .096 | 742 | 689 | .93 |
| | 3 | .090 | 839 | 774 | .92 | .080 | 749 | --- | --- | .096 | 742 | --- | --- |
| | 4 | .090 / .100 | 838 | 798 | .95 | .080 / .090 | 748 | 563 | .75 | .096 / .106 | 741 | --- | --- |
| | 5 | .100 | 836 | 1457 | --- | .090 | 747 | 444 | .59 | .106 | 740 | --- | --- |
| | 6 | .100 | 836 | double | --- | .090 | 747 | --- | --- | .106 | 740 | --- | --- |
| | 7 | .100 | 836 | 685 | .82 | .090 | 747 | --- | --- | .106 | 740 | --- | --- |
| | 8 | .100 / .110 | 834 | 715 | .86 | .090 / .100 | 745 | --- | --- | .106 / .116 | 738 | --- | --- |
| | 9 | .110 | 833 | 748 | .90 | .100 | 744 | 477 | .64 | .116 | 737 | --- | --- |
| | 10 | .110 | 833 | 707 | .85 | .100 | 744 | --- | --- | .116 | 737 | --- | --- |
| | 11 | .110 | 833 | --- | --- | .100 | 744 | 967 | --- | .116 | 737 | --- | --- |
| | 12 | .110 / .120 | 831 | 715 | .86 | .100 / .110 | 743 | DPL | --- | .116 / .126 | 735 | --- | --- |
| | 13 | .120 | 830 | 696 | .84 | .110 | 742 | 565 | .76 | .126 | 734 | --- | --- |
| | 14 | .120 | 830 | --- | --- | .110 | 742 | --- | --- | .126 | 734 | --- | --- |
| NON-BOOSTER END | 15 | .120 | 830 | --- | --- | .110 | 742 | --- | --- | .126 | 734 | --- | --- |

[1] END-RING ATTACHED

WEIGHTS OF RECOVERED FRAGMENTS WHICH WERE IDENTIFIABLE BY FRAGMENT ROW
TEST QN0225A0

| GROOVE-SPACING (circumferential) | | | 7/8-inch SPACING | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTH | INSIDE | | 0.090-inch | | | | 0.100-inch | | | |
| | OUTSIDE | | 0.090-inch | | | | 0.100-inch | | | |
| | | FRAGMENT ROW | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT |
| BOOSTER END | | 1 | .100 | 648 | --- | --- | .112 | 643 | 611 | .95 |
| | | 2 | .100 | 648 | 597 | .92 | .112 | 643 | 599 | .93 |
| | | 3 | .100 | 648 | 591 | .91 | .112 | 643 | --- | --- |
| | | 4 | .100/.110 | 647 | 596 | .92 | .112/.122 | 642 | --- | --- |
| | | 5 | .110 | 646 | 585 | .90 | .122 | 641 | --- | --- |
| | | 6 | .110 | 646 | --- | --- | .122 | 641 | --- | --- |
| | | 7 | .110 | 646 | 477 | .74 | .122 | 641 | 596 | .93 |
| | | 8 | .110/.120 | 644 | --- | --- | .122/.132 | 640 | --- | --- |
| | | 9 | .120 | 643 | --- | --- | .132 | 638 | 548 | .86 |
| | | 10 | .120 | 643 | --- | --- | .132 | 638 | --- | --- |
| | | 11 | .120 | 643 | --- | --- | .132 | 638 | 591 | .93 |
| | | 12 | .120/.130 | 641 | --- | --- | .132/.142 | 637 | 553 | .87 |
| | | 13 | .130 | 640 | --- | --- | .142 | 635 | --- | --- |
| | | 14 | .130 | 640 | --- | --- | .142 | 635 | 548 | .86 |
| NON-BOOSTER END | | 15 | .130 | 640 | --- | --- | .142 | 635 | --- | --- |



FIGURE 225-17

WEIGHT OF FRAGMENTS WHICH WERE IDENTIFIABLE BY FRAGMENT ROW

TEST QN0225A0

| GROOVE-SPACING (circumferential) | | 3/4-inch SPACING | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTH INSIDE | | 0.110-inch | | | | 0.120-inch | | | | 0.110-inch | | | |
| LONGITUDINAL GROOVE DEPTH OUTSIDE | | 0.110-inch | | | | 0.120-inch | | | | 0.080-inch | | | |
| | FRAGMENT ROW | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT |
| BOOSTER END | 1 | .119 | 545 | 528 | .97 | .118 | 542 | 470 | .87 | .103 | 552 | 565 | 1.02 |
| | 2 | .119 | 545 | 487 | .89 | .118 | 542 | 456 | .84 | .103 | 552 | 322(S) | .58 |
| | 3 | .119 | 545 | 501 | .92 | .118 | 542 | --- | --- | .103 | 552 | 1095 | --- |
| | 4 | .119/.129 | 544 | 468 | .86 | .118/.128 | 541 | --- | --- | .103/.113 | 551 | double | --- |
| | 5 | .129 | 542 | 471 | .87 | .128 | 540 | 428 | .79 | .113 | 550 | 534 | .97 |
| | 6 | .129 | 542 | --- | --- | .128 | 540 | 428 | .79 | .113 | 550 | double | --- |
| | 7 | .129 | 542 | --- | --- | .128 | 540 | 428 | .79 | .113 | 550 | double | --- |
| | 8 | .129/.139 | 541 | 467 | .86 | .128/.138 | 538 | 428 | .80 | .113/.123 | 549 | 495 | .90 |
| | 9 | .139 | 540 | 462 | .86 | .138 | 537 | 414 | .77 | .123 | 548 | 490 | .89 |
| | 10 | .139 | 540 | --- | --- | .138 | 537 | --- | --- | .123 | 548 | 497 | .91 |
| | 11 | .139 | 540 | --- | --- | .138 | 537 | --- | --- | .123 | 548 | 541 | .99 |
| | 12 | .139/.149 | 538 | 463 | .86 | .138/.148 | 535 | --- | --- | .123/.133 | 547 | 496 | .91 |
| | 13 | .149 | 537 | --- | --- | .148 | 534 | --- | --- | .133 | 545 | 504 | .92 |
| | 14 | .149 | 537 | 451 | .84 | .148 | 534 | --- | --- | .133 | 545 | 507 | .93 |
| NON-BOOSTER END | 15 | .149 | 537 | 473 | .88 | .148 | 534 | --- | --- | .133 | 545 | --- | --- |

WEIGHTS OF ALL FRAGMENTS (INCLUDING THOSE NON-IDENTIFIABLE BY ROW), TEST QN0225AC

| LONGITUDINAL GROOVE SPACING | 1-1/8-inch | | 1-inch | | | | 7/8-inch | | | | 3/4-inch | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTHS INSIDE | 0.100-inch | | 0.090-inch | | 0.090-inch | | 0.090-inch | | 0.100-inch | | 0.110-inch | | 0.120-inch | | 0.110-inch | |
| LONGITUDINAL GROOVE DEPTHS OUTSIDE | 0.080-inch | | 0.060-inch | | 0.090-inch | | 0.090-inch | | 0.100-inch | | 0.110-inch | | 0.120-inch | | 0.080-inch | |
| CIRCUMFERENTIAL GROOVE DEPTH | 0.090-0.120 inch | | 0.080-0.110 inch | | 0.096-0.126 inch | | 0.100-0.130 inch | | 0.112-0.142 inch | | 0.119-0.149 inch | | 0.118-0.148 inch | | 0.103-0.133 inch | |
| AVERAGE THEORETICAL WEIGHT (grooves) | 835 | | 745 | | 738 | | 644 | | 639 | | 541 | | 538 | | 549 | |
| | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT |
| | 1060[1] | --- | 563 | .76 | 699 | .93 | 597 | .92 | 611 | .95 | 528 | .97 | 470 | .87 | 565[1] | 1.02 |
| | 788 | .94 | 444 | .60 | 1401[7] | --- | 591 | .91 | 599 | .93 | 487 | .8. | 456 | .84 | 322[4] | --- |
| | 774 | | 477 | .64 | 665 | .90 | 332[4] | --- | 596 | .93 | 501 | .92 | 428 | .79 | 1095[5] | --- |
| | 798 | .95 | 967[8] | --- | 656 | .89 | 596 | .92 | 548 | .86 | 468 | .86 | 428 | .79 | 534 | .97 |
| | 1457[2] | --- | 565 | .76 | 680 | .92 | 585 | .90 | 591 | .93 | 471 | .87 | 428 | .79 | 1066 | --- |
| | 685 | .82 | 576 | .77 | 685 | .93 | 477[3] | --- | 553 | .87 | 467 | .85 | 428 | .80 | 495 | .90 |
| | 715 | .86 | 647 | .87 | 699 | .94 | 600[3] | .93 | 548 | .86 | 462 | .86 | 414 | .77 | 430 | .89 |
| | 748 | .90 | 625 | .84 | 682 | .92 | | | 588 | .92 | 463 | .86 | 437 | .81 | 497 | .91 |
| | 707 | .85 | 654 | .88 | 694 | .94 | | | 537 | .92 | 451 | .84 | 433 | .80 | 541 | .99 |
| | 715 | .86 | | | 667 | .89 | | | 581 | .91 | 473 | .88 | 439 | .82 | 496 | .91 |
| | 696 | .84 | | | 659 | .89 | | | 594 | .93 | 528 | .98 | 422 | .78 | 504 | .92 |
| | 724[3] | .87 | | | | | | | 591 | .92 | | | 427 | .79 | 507 | .93 |
| | 708[3] | .85 | | | | | | | 590 | .92 | | | 454 | .84 | 434 | .90 |
| | 738 | .88 | | | | | | | 550 | .86 | | | | | 484 | .88 |
| | 738 | .88 | | | | | | | 544 | .85 | | | | | 488 | .89 |
| | | | | | | | | | 588 | .92 | | | | | 484 | .88 |
| | | | | | | | | | 559 | .87 | | | | | 514 | .94 |
| | | | | | | | | | | | | | | | 490 | .89 |
| | | | | | | | | | | | | | | | 493 | .90 |
| | | | | | | | | | | | | | | | 485 | .89 |
| | | | | | | | | | | | | | | | 496 | .91 |
| | | | | | | | | | | | | | | | 414[3] | .76 |

[1]BOOSTER-END END-RING ATTACHED TO FRAGMENT
[2]FRAGMENT DOUBLE, ROWS 5, 6
[3]FRAGMENT DAMAGED BY STEEL BANDS ON CELOTEX
[4]FRAGMENT SPALLED
[5]FRAGMENT DOUBLE, ROWS 3, 4
[6]FRAGMENT DOUBLE, ROWS 6, 7
[7]FRAGMENT DOUBLE (ROWS UNKNOWN)
[8]FRAGMENT DOUBLE, ROWS 11, 12



FIGURE 225-19

TEST QN0311A0

11.5", 135-LB FIREFORMED-FRAGMENT WARHEAD

## 2.1.3 TEST 2, QN0311A0

### 2.1.3.1 DESIGN SUMMARY AND RATIONALE

The basic design characteristics of the warhead (Figure 311-1) in this test were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 11.5-inch |
| INSIDE DIAMETER: | 2.875-inch |
| LENGTH: | 14.0-inch |
| CASE THICKNESS: | 0.5-inch |
| CASE MATERIAL: | SAE 4140, (RC40-42) |
| FRAGMENT TYPE: | Fireformed |
| WEIGHT: | 135-lb |
| SHROUD: | Double walled steel, 0.020-inch inside, 0.030-inch steel outside, with 1-inch urethane foam between warhead and shroud |

The 2.875-inch-inside diameter is a typical cavity size for safe-and-arm devices in warheads of this size. The length and case-thickness combination was designed to provide for fragment velocities between 5000- and 5500-ft/sec, after passing through the missile shroud. SAE 4140 case-material was used because the design-choice of SAE 4130 tubing could not be found in this size. The warhead was designed to generate 15 rows of equal-length fragments (0.867-inch long). The ends of the warhead were tapered to reduce end effects on fragment pattern and velocity. Three choices of spacing between the longitudinal grooves were tested (0.75-, 0.906-, and 1.188-inch inside-spacing). The theoretical weights of these fragments (after grooving but with no loss due to fire-forming) are about 630-, 780-, and 1010-grains, respectively. The amount of weight in excess of the nominal values of 500, 700, was expected to be lost during firing.

The first test, QN0225A0 was a success in that excellent quality fragments were generated. In this following test, however, the warhead case was thicker (0.5-inch vs 0.438-inch). There were several design approaches which were possible for the opposed grooves. Proper fireforming of fragments could be dependent on:

1. The depths of the inside and outside grooves (or sum of the depths).

2. The ratio of the depths of the grooves to the case thickness.

3. The thickness of the metal remaining between the apexes of the opposed grooves.

For this test, the decision was made to use approaches 1 and 2.

## A. Longitudinal Grooves

Opposed groove designs having depths of 0.100, 0.110, and 0.120-inch (inside and outside) worked well in the previous test, so these designs were repeated. In the event that the case thickness increase from 0.438-inch to 0.5-inch is significant, groove depths of 0.130-inch (inside and outside) will be tested, which is approximately in the same ratio of groove depth to case thickness as the 0.120-inch grooves in the previous test. One relatively shallow opposed groove design (0.100-inch deep inside, 0.080-inch outside) was also tested to provide for the event that shallower grooves might be either required or sufficient. The longitudinal groove designs are summarized in the table below.

| INSIDE GROOVE DEPTH (inch) | OUTSIDE GROOVE DEPTH (inch) | METAL REMAINING BETWEEN GROOVES (inch) |
|---|---|---|
| 0.100 | 0.080 | 0.320 |
| 0.100 | 0.100 | 0.300 |
| 0.100 | 0.110 | 0.280 |
| 0.120 | 0.120 | 0.260 |
| 0.130 | 0.130 | 0.240 |

## B. Circumferential Grooves

The fragments from the rows nearest the booster end which were deemed "best" in test ON0225A0 resulted from opposed groove depths of 0.100 to 0.110-inch deep. The average value of these depths was increased by the ratio of 0.5-inch case thickness to 0.438-inch case thickness for this test (i.e. $0.105" \times \frac{0.5}{0.438} = 0.120"$). The depths of the four grooves nearest the booster end were then varied ±0.020-inch about this value.

The same procedure was followed for the remaining (non-booster end) grooves: The "best" non-booster end fragments from 225 were generated from groove depths of 0.123 to 0.133-inch, thus, $0.128 \times \frac{0.5}{0.438} = 0.146$-inch. Groove depths were then varied from 0.130 to 0.160-inch. The groove designs are summarized in the table below.

The circumferential grooves are numbered sequentially, starting with the groove nearest the booster end.

| GROOVE NUMBER | MINIMUM GROOVE DEPTH (inch) | MAXIMUM METAL REMAINING BETWEEN GROOVES (inch) | MAXIMUM GROOVE DEPTH (inch) | MINIMUM METAL REMAINING BETWEEN GROOVES (inch) |
|---|---|---|---|---|
| 1 | 0.160 | 0.180 | 0.160 | 0.180 |
| 2 through 5 | 0.100 | 0.300 | 0.140 | 0.220 |
| 6 through 15 | 0.130 | 0.240 | 0.160 | 0.180 |
| 16 | 0.160 | 0.180 | 0.160 | 0.180 |

2.1.3.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENA

The objective of the test was to recover a sample of each groove-design choice, and to measure fragment ejection angles and fragment velocities. The test arena (Figure 311-7) consisted of seven celotex packs and six steel witness sheets. Photographs of the test arena are presented in Figures 311-11 and 311-12. Fastax cameras were used to measure fragment velocities.

2.1.3.3 DESCRIPTION OF TEST RESULTS

A. Fragment Quality

1. Longitudinal Grooving

The longitudinal-groove breakout-quality was a function of the metal remaining between the apexes of the opposed grooves.* When the metal remaining was 0.240-inch, the desired fragment quality was achieved (Figure 311-3). For metal remaining values between 0.240-inch and 0.260-inch, borrowing occurred (Figure 311-4); for metal thicknesses greater than 0.280-inch, partials occurred (Figure 311-5).

2. Circumferential Grooving

No fragment doubles occurred for fragment rows 1 and 2. Fragment doubles were recovered for rows 3, 4, and 5 where the metal remaining between apexes of the grooves was 0.240-inch or more. Fragment doubles occurred for all choices of circumferential groove depth for fragment rows 6 through 15.

* The designers did not recognize this until much later in the program.

## B. Fragment Velocity and Pattern

Because of the lengthwise pairing of fragments, the fragment polar-ejection-angles for this test are suspect. The coordinates of all the fragment hits are presented in Figure 311-8 and 311-9, with an estimate as to which fragments were paired.

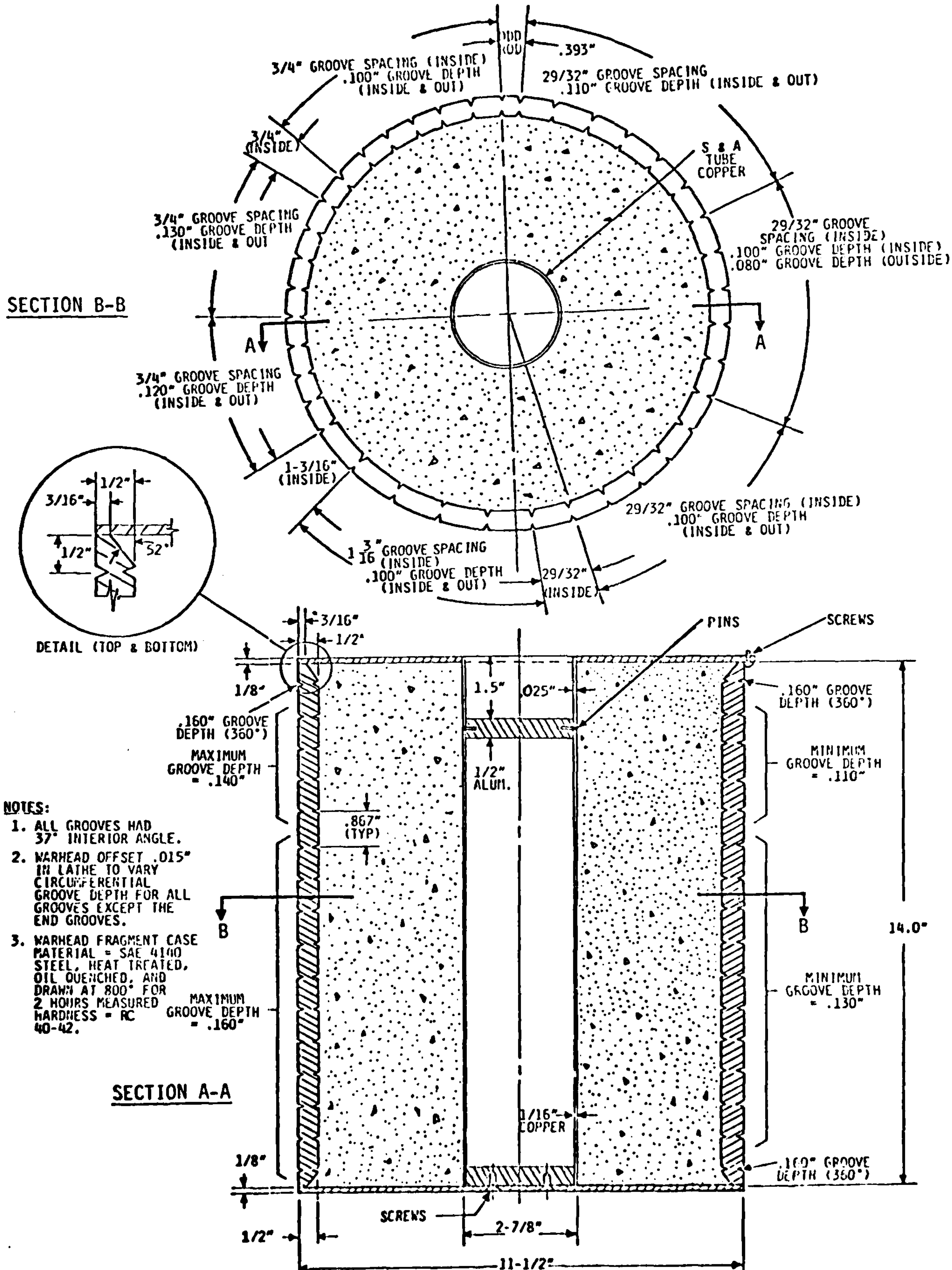
The Fastax films yielded good time-of-arrival data, and fragment velocities are presented in Figure 311-10. Photographs of the witness sheets are presented in Figures 311-12 through 311-15.

## C. CONCLUSIONS

1. The warhead design will have to be altered to achieve proper case breakout and achieve the desired fragment sizes and shapes.

2. The "best" fragments resulted for the following opposed groove designs:

| | |
|---|---|
| LONGITUDINAL GROOVES: | 0.100-inch deep (inside and out) for rows 2 through 7.<br>0.130-inch deep (inside and out) for rows 8 through 15. |
| CIRCUMFERENTIAL GROOVES: | 0.130-inch deep (inside and outside) for rows 2 through 5.<br>0.158-inch deep (inside and outside) for rows 6 through 15. |

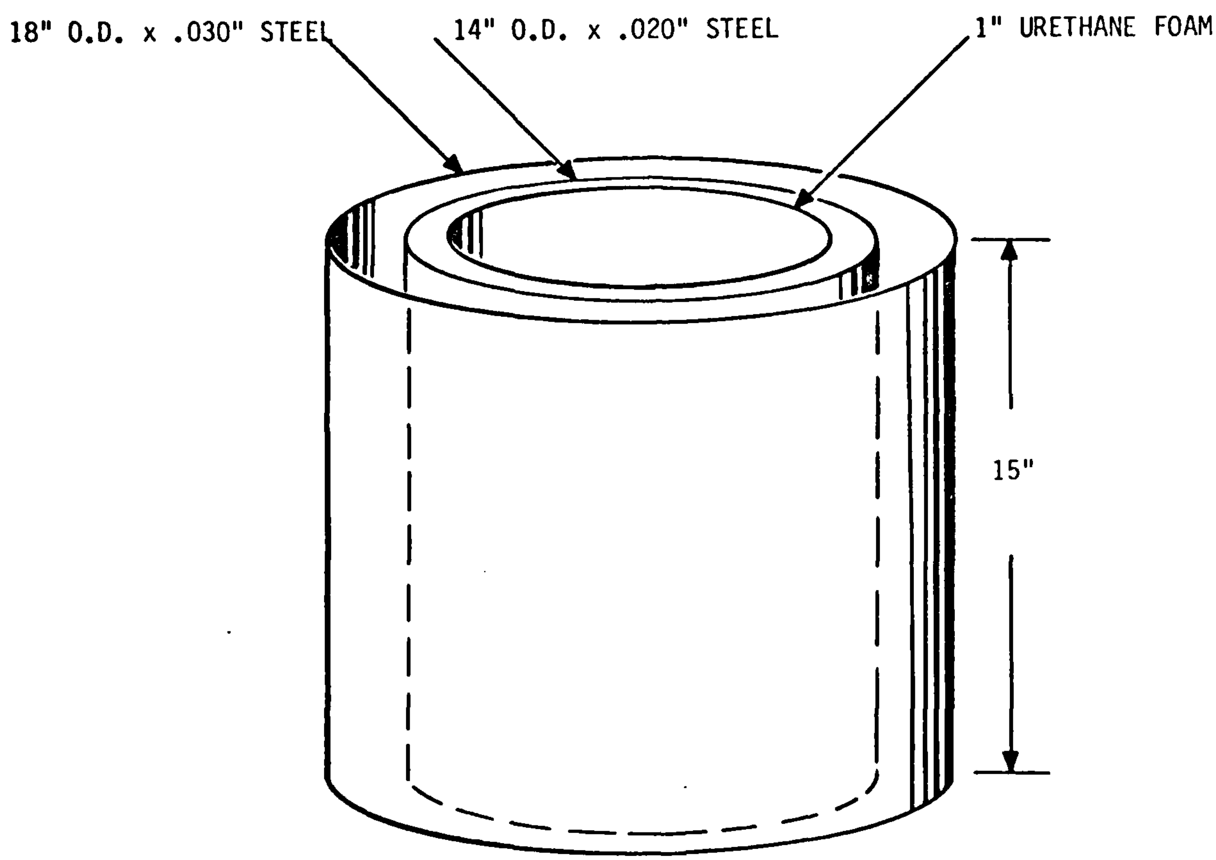



11-1/2" O.D., 135-LB FIRE-FORMED HIBAL WARHEAD

TEST QN0311A0

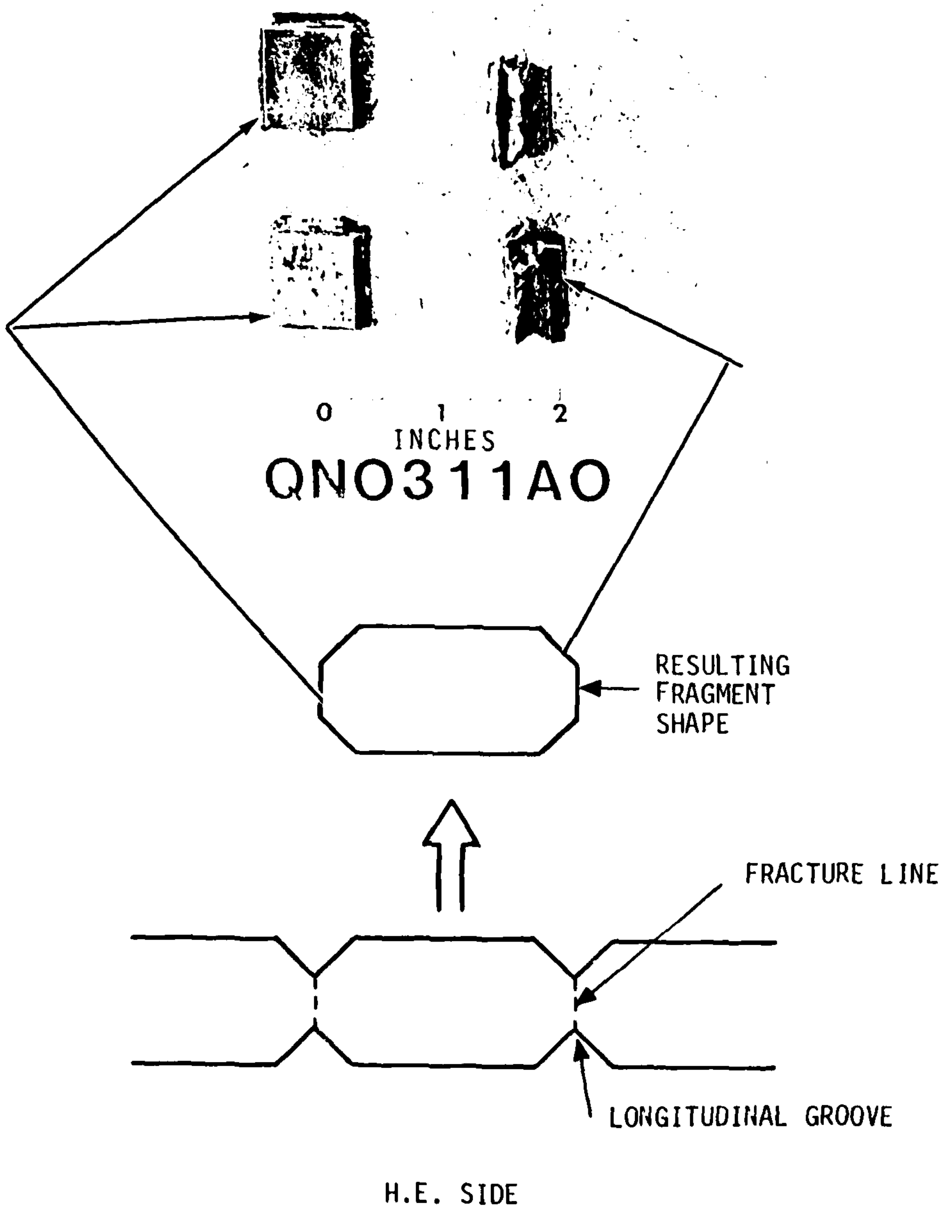


FIGURE 311-1



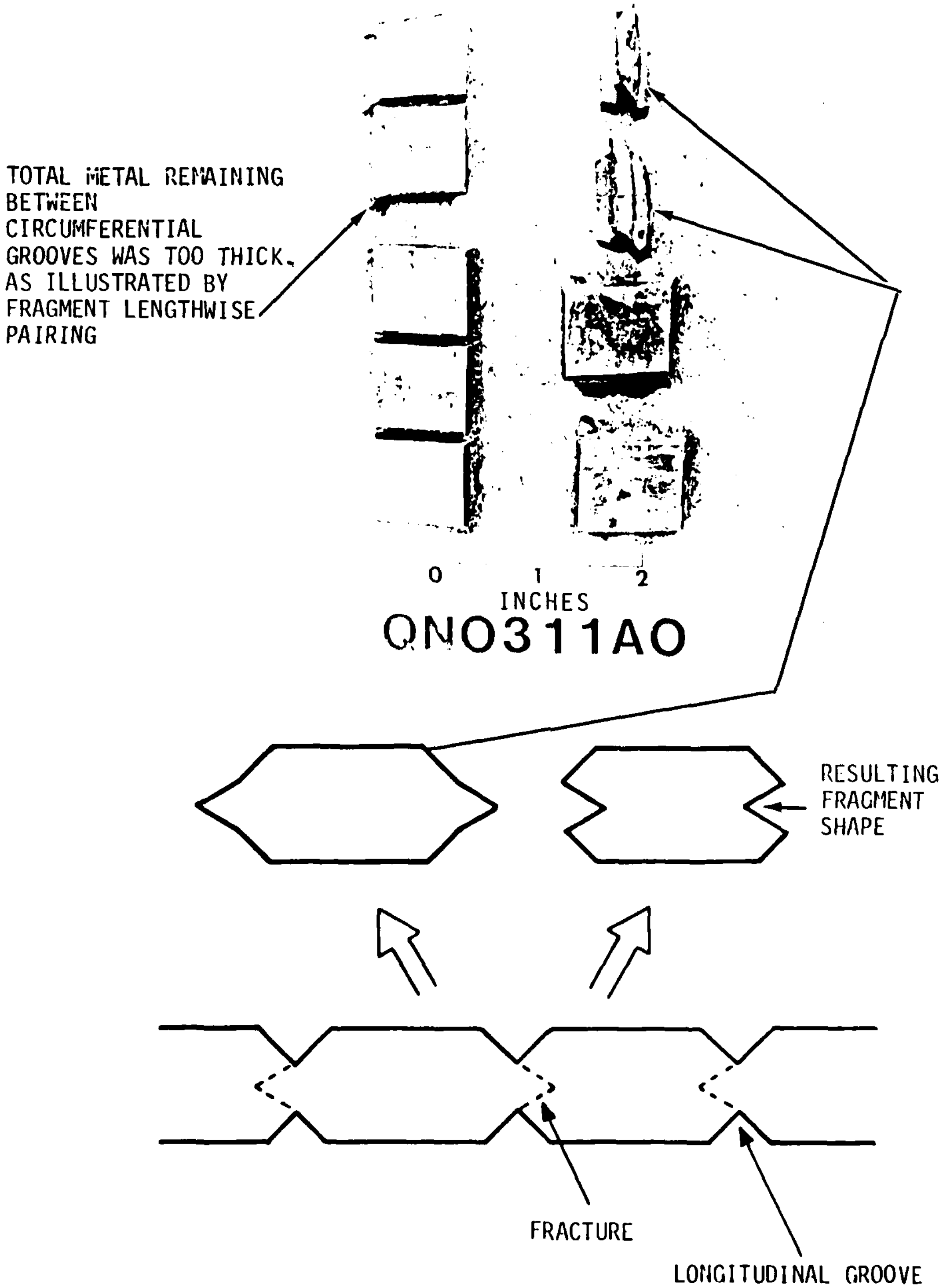

SHROUD FOR 11-1/2" O.D., 135-LB WARHEAD

TEST QN0311A0



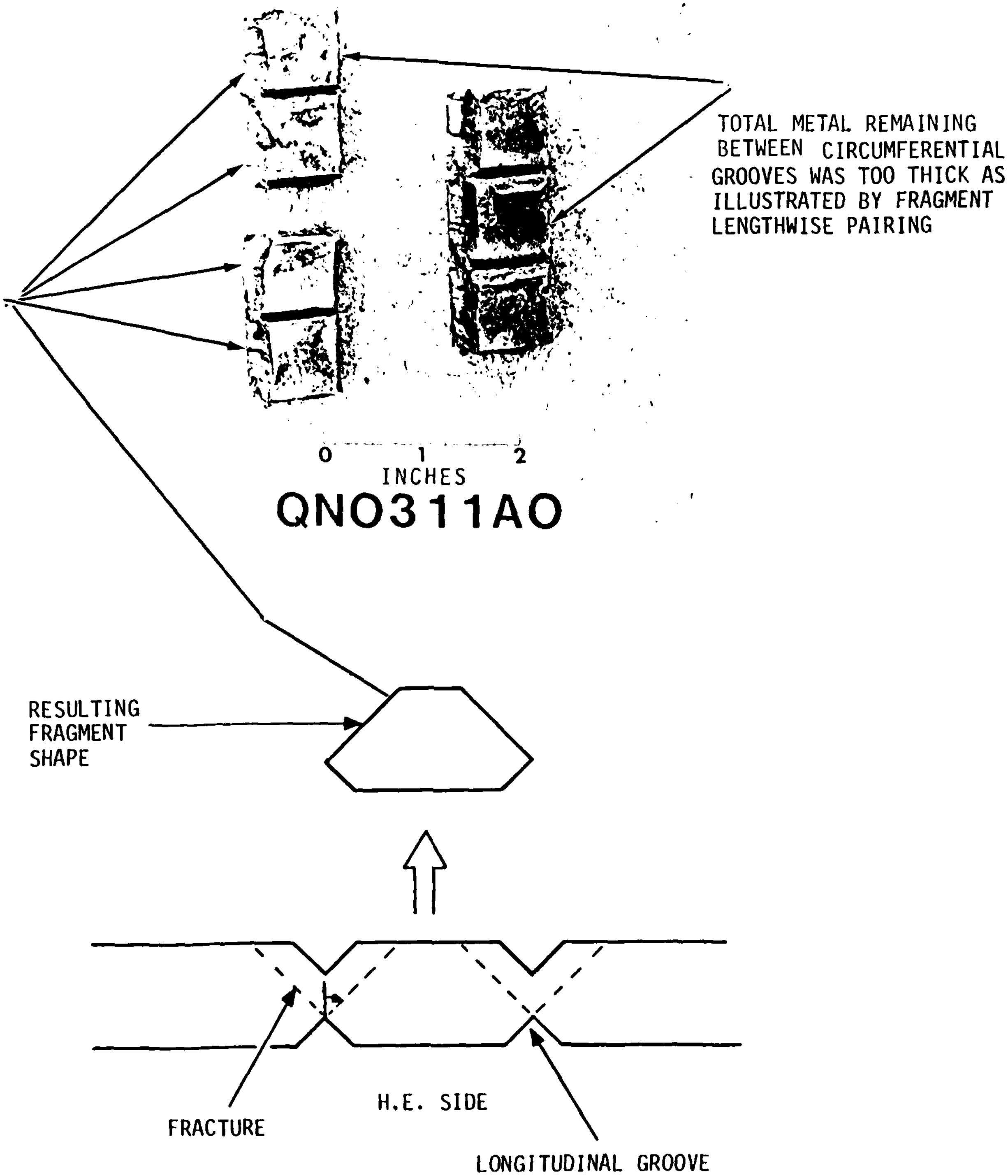

FRAGMENT SHAPE RESULTING WHEN THE METAL REMAINING BETWEEN LONGITUDINAL INSIDE AND OUTSIDE GROOVES IS BETWEEN 0.200" AND 0.240"

EXAMPLE FRAGMENTS FROM TEST QNO311AO




REDUCED-WEIGHT FRAGMENTS RESULTING WHEN THE METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.240" THROUGH 0.260"

EXAMPLE FRAGMENTS FROM TEST QN0311A0




REDUCED-WEIGHT FRAGMENTS RESULTING WHEN METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.280" OR MORE

EXAMPLE FRAGMENTS FROM TEST QN0311A0

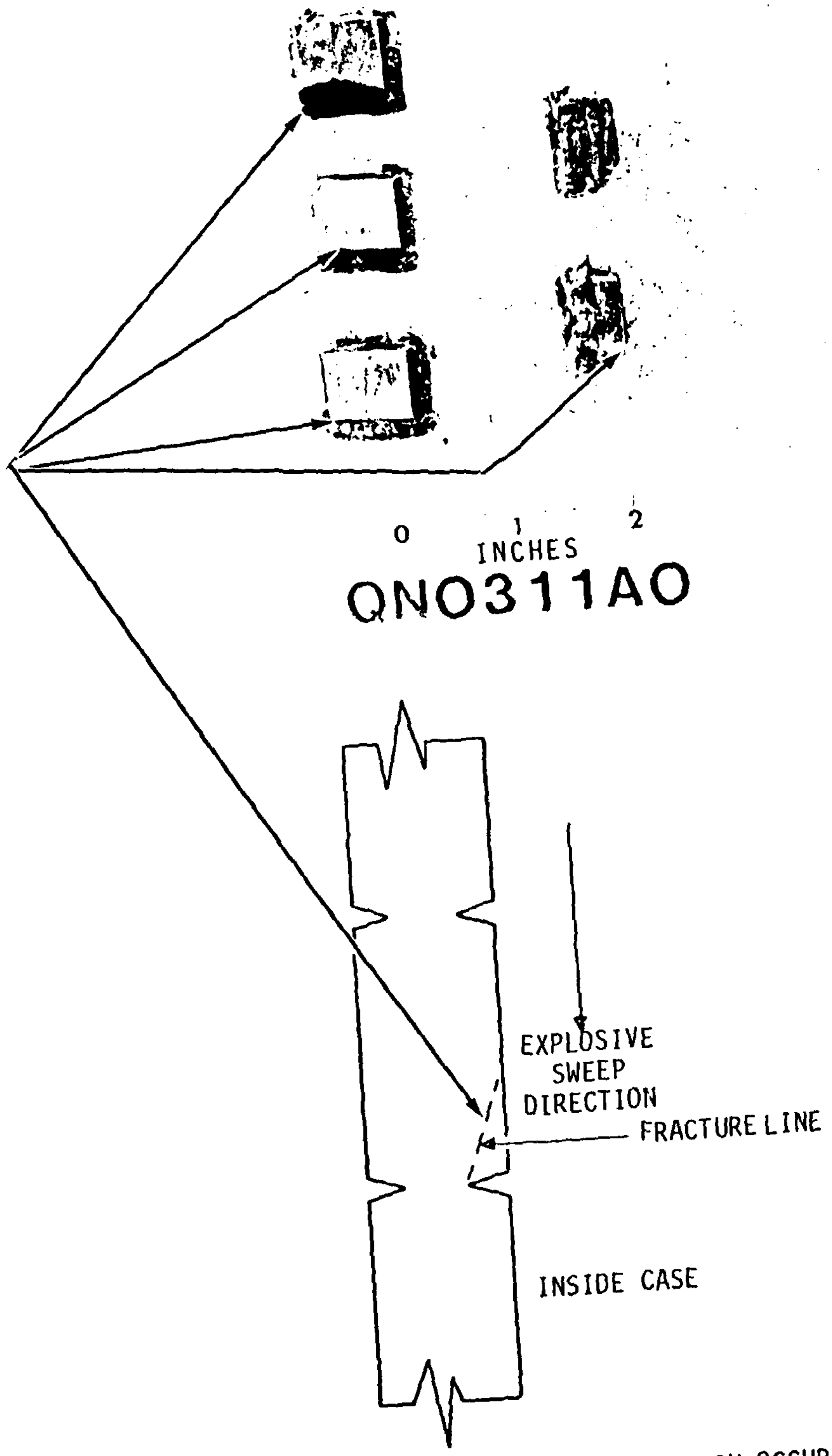



ILLUSTRATION SHOWING THE FRACTURE WHICH OCCURRED WHEN THE INSIDE CIRCUMFERENTIAL GROOVES EXCEEDED 0.120" DEPTH

EXAMPLE FRAGMENTS FROM TEST QNO311AO

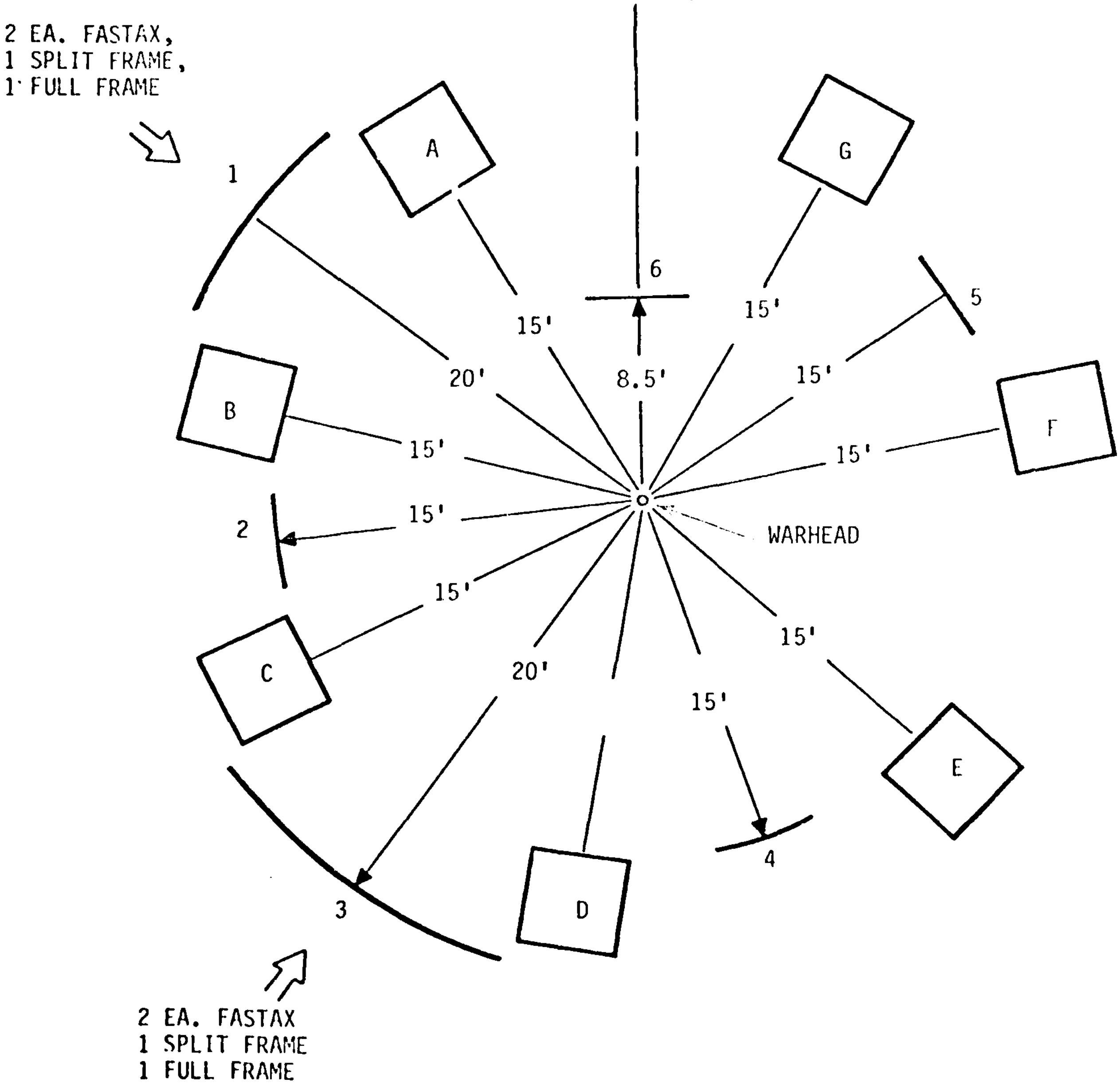
FIGURE 311-6

TARGETS A, B, C, D, E, F, G = 4'x4'x8' CELOTEX PACKS WITH 1/2" STEEL BACKPLATE

TARGETS 1, 3 = 2 EA. .105" STEEL PLATES 8' HIGH SPACED 3" APART

TARGETS 2, 4, 5 = 1 EA. .105" STEEL PLATE 4' WIDE, 8' HIGH

TARGET 6 = 4'x'6'x1/2" MILD STEEL




ARENA FOR
TEST QN0311A0
11-1/2-INCH O.D., 135-LB FIREFORMED WARHEAD



FIGURE 311-7

TEST QN0311A0

COORDINATES* OF FRAGMENT HIT LOCATIONS (INCHES) ON WITNESS SHEETS NOS. 2, 4, AND 5 AT 15' RADIUS

| FRAGMENT ROW | WITNESS SHEET #2 | | | | WITNESS SHEET #4 | | | | WITNESS SHEET #5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COLUMN 1 | | COLUMN 2 | | COLUMN 1 | | COLUMN 2 | | COLUMN 1 | | COLUMN 2 | |
| | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. |
| 1 | -- | -- | | | | | 21 | +25 | 3 | +18 | 32 | 17 |
| 2 | -- | -- | 19 | +24 | -- | -- | 22 | +16 | 4 | + 5 | 34 | 5 |
| 3 | -- | -- | 18 | + 9 | -- | -- | 24 | - 6** | 6 | - 9 | 38 | -12** |
| 4 | -- | -- | 20 | - 3 | -- | -- | 24 | - 6** | 6 | - 9 | 38 | -12** |
| 5 | -- | -- | 22 | -10 | -- | -- | 24 | - 6** | 6 | - 9 | 38 | -12** |
| 6 | -- | -- | 26 | -21 | -- | -- | 28 | -13** | 7 | 19 | 42 | -17 |
| 7 | -- | -- | 28 | -21 | -- | -- | 28 | -13** | 12 | -23** | 44 | -23 |
| 8 | -- | -- | 31 | -31** | -- | -- | 32 | -26** | 12 | -23** | 47 | -26** |
| 9 | -- | -- | 31 | -31** | -- | -- | 32 | -20** | 12 | -23** | 47 | -26** |
| 10 | -- | -- | 31 | -31 | 2 | -25** | 36 | -28** | 16 | -28** | 47 | -26** |
| 11 | 2 | -25 | 31 | 31** | 2 | -25** | 36 | -28** | 16 | -28** | -- | --- |
| 12 | 5 | -30 | 31 | 31 | 2 | -25** | 36 | -28** | 16 | -28** | -- | --- |
| 13 | 5 | -30 | 35 | -34 | 8 | -30** | 42 | -32** | 22 | 35** | -- | --- |
| 14 | 10 | -31 | 35 | -34 | 8 | -30** | 42 | -32** | 22 | -35** | -- | --- |
| 15 | 11 | -33 | 35 | -34 | 12 | -36 | 44 | -40 | 22 | -35** | -- | --- |

* VERTICAL MEASUREMENTS ARE REFERENCED FROM THE TOP (BOOSTER END) OF THE WARHEAD. HORIZONTAL MEASUREMENTS ARE REFERENCED FROM THE LEFT HAND SIDE OF THE WITNESS SHEET AS VIEWED FROM THE WARHEAD.

** INDICATES FRAGMENT PAIRING (LENGTHWISE).

FIGURE 311-8

TEST QN0311A0

COORDINATES* OF FRAGMENT HIT LOCATIONS (INCHES) ON WITNESS SHEETS NOS. 1 AND 3 AT 20-FT RADIUS

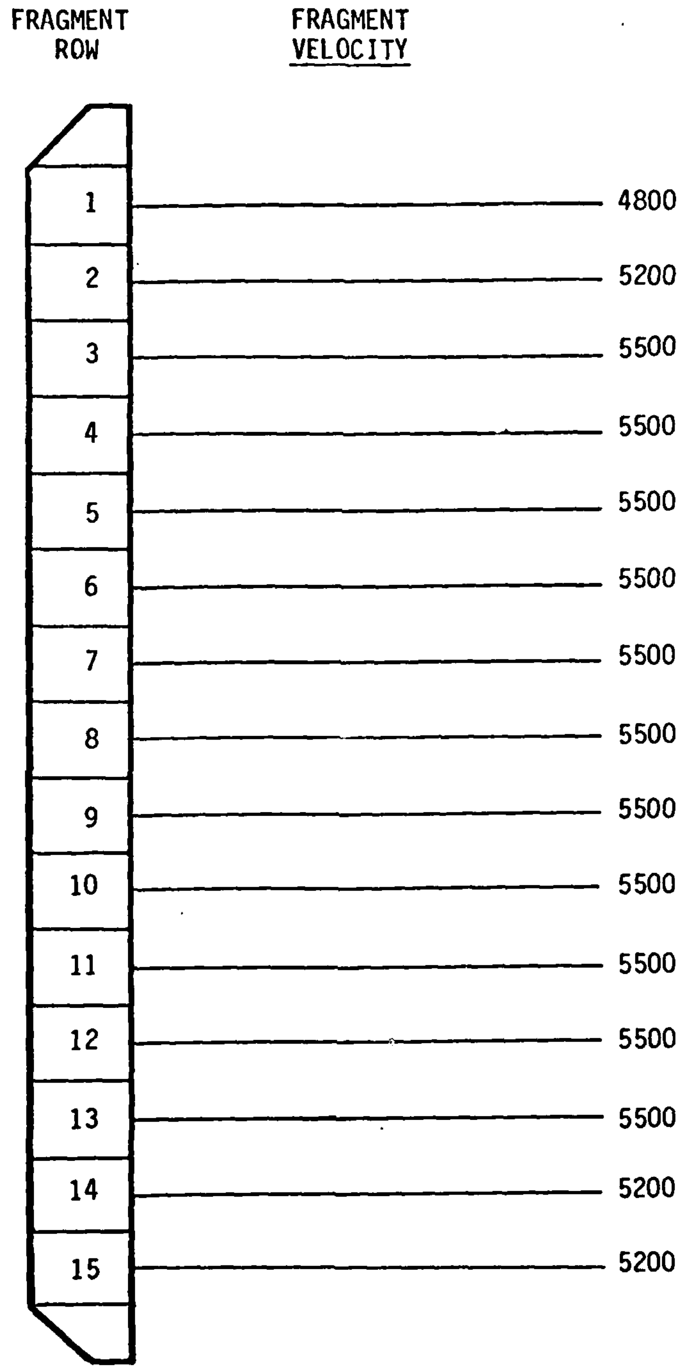
| FRAGMENT ROW | WITNESS SHEET #1 | | | | | | WITNESS SHEET #2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COLUMN 1 | | COLUMN 2 | | COLUMN 3 | | COLUMN 1 | | COLUMN 2 | | COLUMN 3 | |
| | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. | HORIZ. DIST. | VERT. DIST. |
| 1 | -- | -- | 46 | +30 | 79 | 29 | 5 | +31 | 61 | +31 | 114 | +27 |
| 2 | 14 | +15 | 47 | + 6 | 80 | 17 | 6 | +26 | 64 | +28 | 111 | +25 |
| 3 | 16 | 0 | 52 | 0 | 84 | - 2 | 11 | - 4** | 68 | - 6 | 120 | - 6** |
| 4 | 19 | - 9 | 56 | - 7** | 88 | - 9 | 12 | - 5** | 69 | - 6 | 120 | - 6** |
| 5 | 19 | - 9 | 56 | - 7** | 89 | -19** | 17 | -17 | 73 | -17** | 124 | -15** |
| 6 | 19 | - 9 | 59 | -17-1/2 | 89 | -19** | 20 | -20 | 73 | -17** | 124 | -15** |
| 7 | 20 | -18 | 60 | -22 | 93 | -25** | 22 | -22 | 76 | -20 | 127 | -21 |
| 8 | 24 | -24 | 61 | -23 | 93 | -25** | 23 | -31 | 76 | -23 | 130 | -24 |
| 9 | 24 | -24 | 67 | -36** | 97 | -35 | 26 | -34 | 78 | -29 | 133 | -31** |
| 10 | 29 | -36 | 67 | -36** | 97 | -35 | 29 | -37 | 83 | -32 | 133 | -31** |
| 11 | 29 | -36 | 67 | -36** | 97 | -35 | 29 | -37 | 83 | -32 | 136 | -34** |
| 12 | 29 | -36 | 70 | -36 | 97 | -35 | 31 | -39 | 85 | -35 | 136 | -34** |
| 13 | 33 | -37 | 79 | -46** | 106 | -42 | 34 | -44 | 89 | -37 | 136 | -34** |
| 14 | 33 | -37 | 79 | -46** | 105 | -45** | 34 | -44 | 92 | -43** | 142 | -43** |
| 15 | 33 | -37 | 79 | -46** | 105 | -45** | 38 | -52 | 92 | -43** | 142 | -43** |

* VERTICAL MEASUREMENTS ARE REFERENCED FROM THE TOP (BOOSTER-END) OF THE WARHEAD. HORIZONTAL MEASUREMENTS ARE REFERENCED FROM THE LEFT HAND SIDE OF THE WITNESS SHEET AS VIEWED FROM THE WARHEAD.

** INDICATES FRAGMENT PAIRING (LENGTHWISE).



FIGURE 311-9

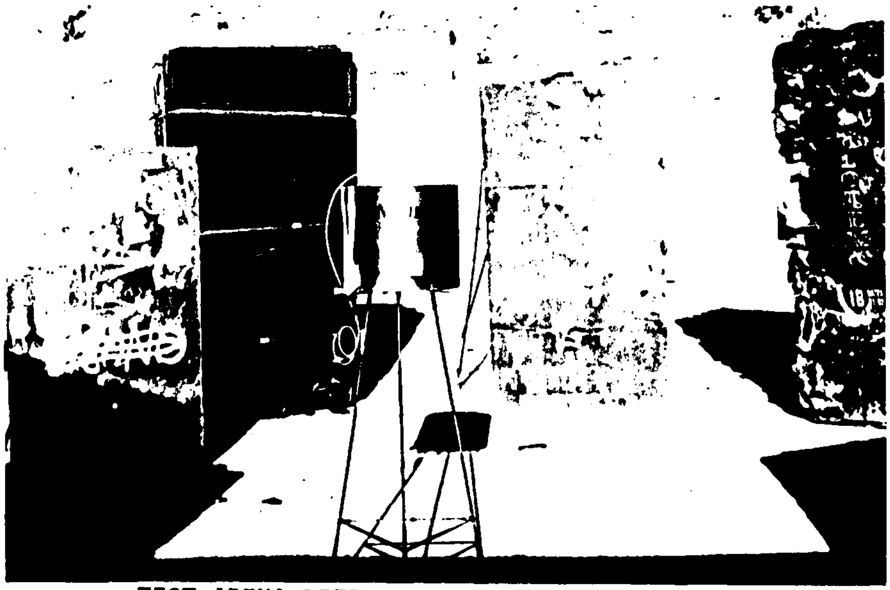



FRAGMENT VELOCITY CHARACTERIZATION
BASED ON TEST QN0311A0 DATA



FIGURE 311-10

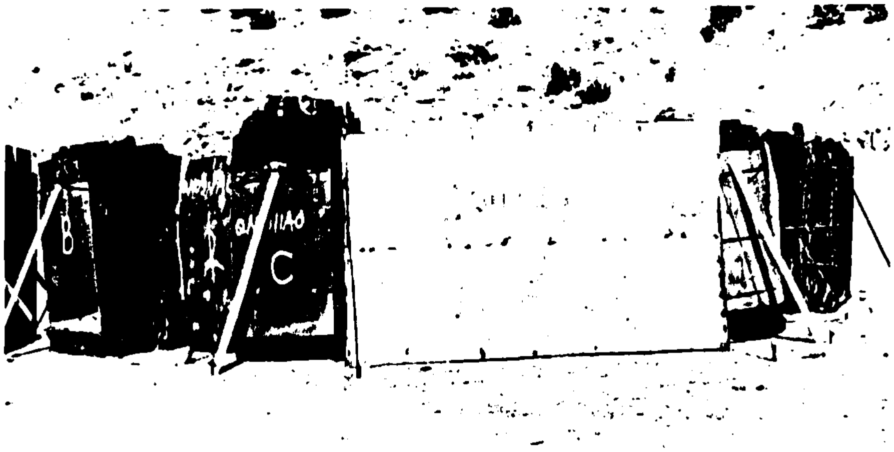

VIEW OF WARHEAD IN THE TEST ARENA WITH THE SHROUD REMOVED



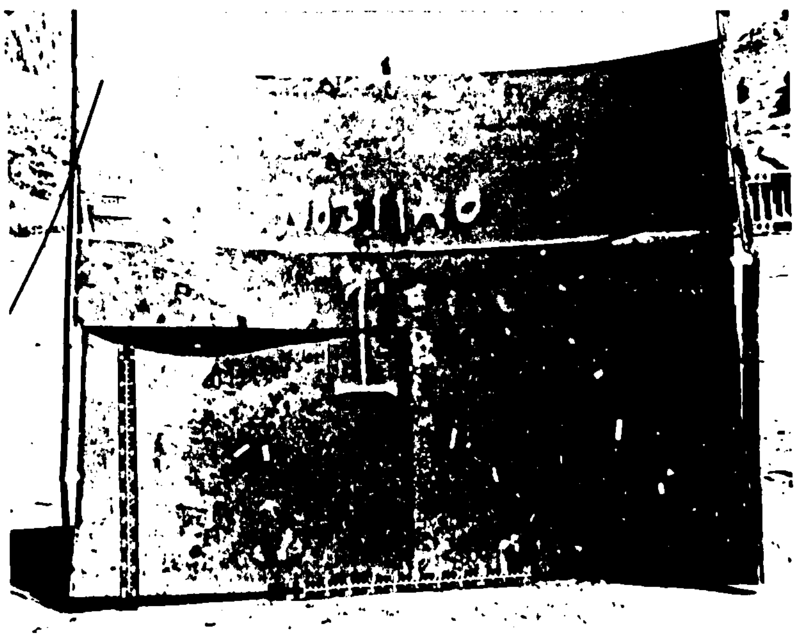
TEST ARENA BEFORE DETONATION SHOWING THE WARHEAD WITH THE SHROUD IN PLACE



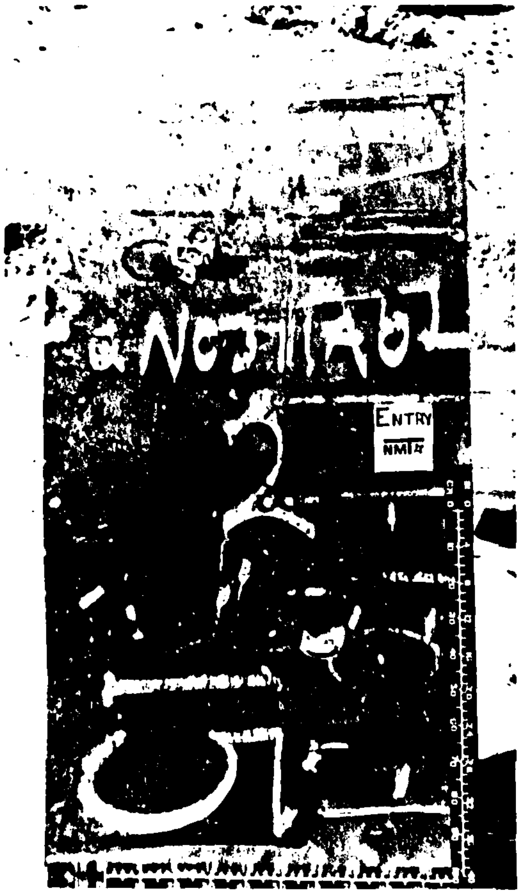
FIGURE 311-11



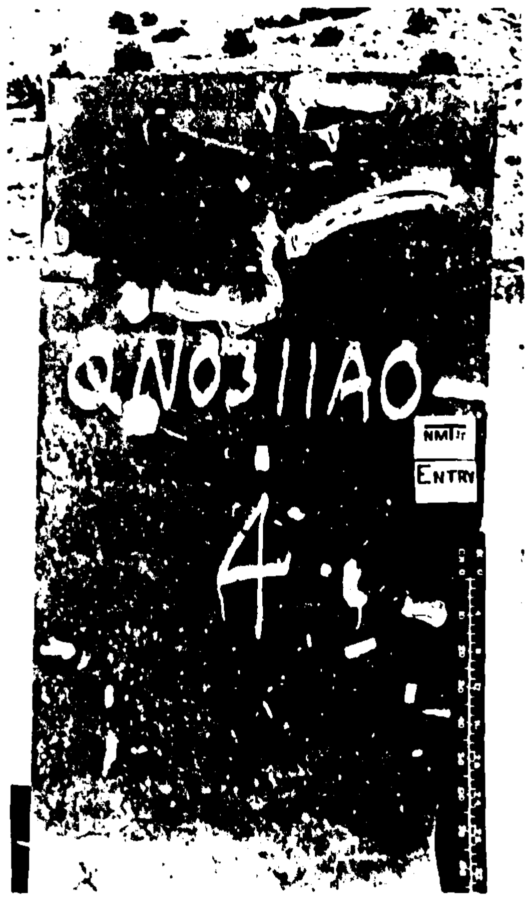

TEST ARENA BEFORE DETONATION



WITNESS SHEET #1 AFTER TEST: 20' RADIUS:
ENTRY SIDE



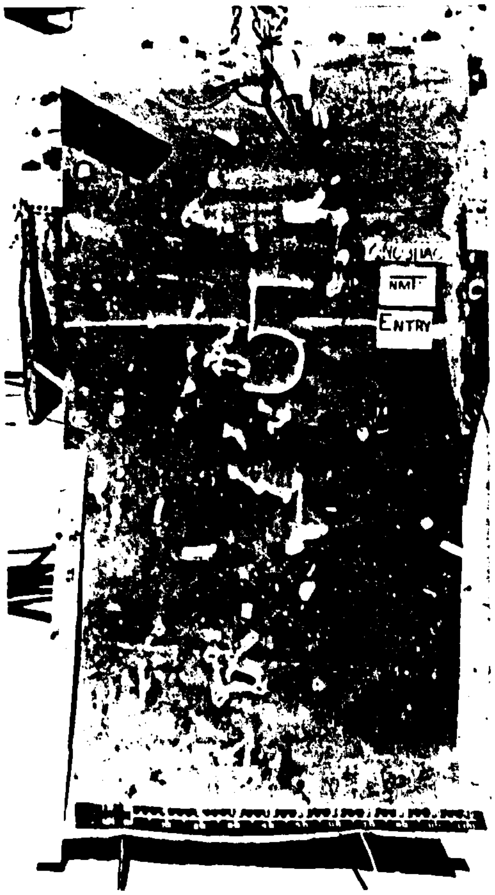

WITNESS SHEET #2 AFTER TEST;
15' RADIUS; ENTRY SIDE



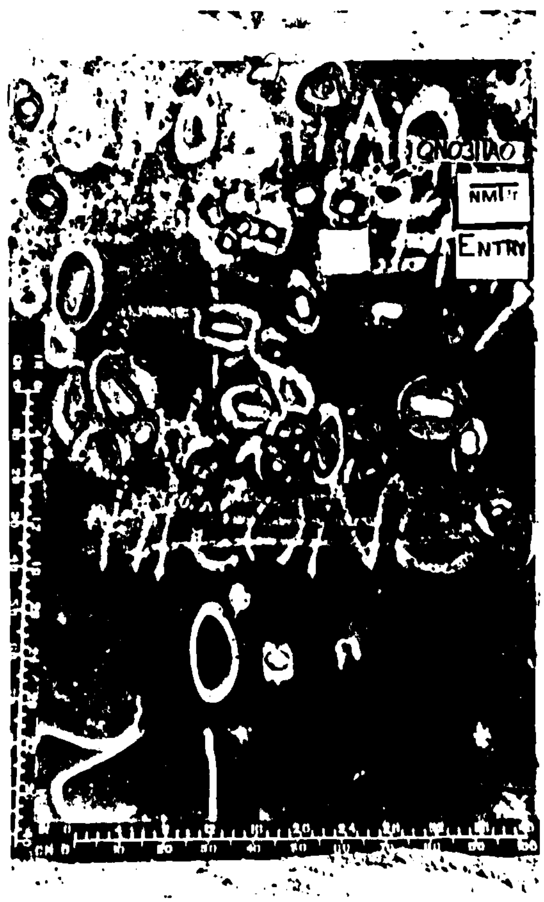

WITNESS SHEET #4 AFTER TEST;
15' RADIUS; ENTRY SIDE



FIGURE 311-13




WITNESS SHEET #5 AFTER TEST; 15' RADIUS; ENTRY SIDE




1/2" STEEL WITNESS SHEET AFTER TEST; 8'6" RADIUS; ENTRY SIDE



FIGURE 311-14


WITNESS SHEET #3 AFTER TEST; 20' RADIUS; ENTRY SIDE



FIGURE 311-15

# WEIGHTS OF RECOVERED FRAGMENTS
## TEST QN0311A0

| GROOVE-SPACING (circumferential) | | 3/4-INCH (INSIDE) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTH INSIDE | | 0.100-inch | | | | 0.120-inch | | | | 0.130-inch | | | |
| LONGITUDINAL GROOVE DEPTH OUTSIDE | | 0.100-inch | | | | 0.120-inch | | | | 0.130-inch | | | |
| | FRAGMENT ROW | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT ÷ THEORETICAL WEIGHT |
| BOOSTER END | 1 | .160/.130 | 636 | --- | --- | .160/.137 | 629 | 265(s) | --- | .160/.138 | 629 | 593/443(s) | .94/ |
| | 2 | .130 | 639 | --- | --- | .137 | 631 | --- | --- | .138 | 631 | | -- |
| | 3 | .130 | 639 | 596 | .93 | .137 | 631 | --- | --- | .138 | 631 | 607/211(s) | .96/-- |
| | 4 | .130 | 639 | 218(m) | --- | .137 | 631 | --- | --- | .138 | 631 | --- | -- |
| | 5 | .130/.150 | 636 | | --- | .137/.157 | 627 | --- | --- | .138/.158 | 627 | --- | -- |
| | 6 | .150 | 632 | 644 | 1.02 | .157 | 623 | 570/579 | .91/.93 | .158 | 623 | 244(s) | -- |
| | 7 | .150 | 632 | 548 | .87 | .157 | 623 | 534 | .86 | .158 | 623 | 539 | .87 |
| | 8 | .150 | 632 | 525 | .83 | .157 | 623 | 531 | .85 | .158 | 623 | 506 | .81 |
| | 9 | .150 | 632 | 469 | .74 | .157 | 623 | 164(s) | --- | .158 | 623 | 556 | .89 |
| | 10 | .150 | 632 | 207(s) | --- | .157 | 623 | 529/154(s) | .85/-- | .158 | 623 | 557/565 | .89/.91 |
| | 11 | .150 | 632 | 182(s) | --- | .157 | 623 | 526/139(s) | .84/ | .158 | 623 | 549 | .88 |
| | 12 | .150 | 632 | | | .157 | 623 | 157(s) | --- | .158 | 623 | 532 | .85 |
| | 13 | .150 | 632 | 428 | .63 | .157 | 623 | --- | --- | .158 | 623 | 543 | .87 |
| | 14 | .150 | 632 | 527/542 | .83/.86 | .157 | 623 | 536 | .86 | .158 | 623 | 537 | .86 |
| NON-BOOSTER END | 15 | .150/.160 | 632 | 235(s)/528 | /.84 | .157/.160 | 625 | --- | --- | .158/.160 | 625 | 556 | .89 |
| ESTIMATED "K" FACTOR FOR DRAG IN FUEL | | | | | | | | | | | | | |

NOTE: (s) AFTER THE FRAGMENT WEIGHT MEANS THAT FRAGMENT SCABBED; (m) AFTER THE FRAGMENT MEANS THAT THE FRAGMENT WAS A MULTIPLE-FRAGMENT



FIGURE 311-16

# WEIGHTS OF RECOVERED FRAGMENTS
## TEST QN0311A0

| GROOVE-SPACING (circumferential) | | 29/32-INCH (INSIDE) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTH INSIDE | | 0.100-inch | | | | 0.100-inch | | | | 0.110-inch | | | |
| LONGITUDINAL GROOVE DEPTH OUTSIDE | | 0.080-inch | | | | 0.100-inch | | | | 0.110-inch | | | |
| | FRAGMENT ROW | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT : THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT : THEORETICAL WEIGHT | CIRCUMFERENTIAL GROOVE DEPTH (inch) | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT : THEORETICAL WEIGHT |
| BOOSTER END | 1 | .160/.112 | 779 | 335(s) | --- | .160/.118 | 772 | 343(s) | --- | .160/.120 | 769 | 673 | .88 |
| | 2 | .112 | 783 | 793 | 1.01 | .118 | 779 | | --- | .120 | 776 | 631 | .81 |
| | 3 | .112 | 783 | 622 | .79 | .118 | 779 | 2011(m) | --- | .120 | 775 | 730 | .94 |
| | 4 | .112 | 783 | | --- | .118 | 779 | | --- | .120 | 776 | 1457(m) | --- |
| | 5 | .112/.132 | 779 | | --- | .118/.138 | 775 | | --- | .120/.140 | 772 | 1457(m) | --- |
| | 6 | .132 | 775 | 1096(m) | --- | .138 | 771 | | --- | .140 | 767 | 500 | .65 |
| | 7 | .132 | 775 | | --- | .138 | 771 | | --- | .140 | 767 | 602 | .78 |
| | 8 | .132 | 775 | 597 | .77 | .138 | 771 | 485 | .63 | .140 | 767 | 678 | .88 |
| | 9 | .132 | 775 | | --- | .138 | 771 | 602 | .78 | .140 | 767 | 690 | .90 |
| | 10 | .132 | 775 | 503 | .66 | .138 | 771 | 681 | .88 | .140 | 767 | 681 | .89 |
| | 11 | .132 | 775 | | --- | .138 | 771 | 1215(m) | --- | .140 | 767 | 1370(m) | --- |
| | 12 | .132 | 775 | 1776(m) | --- | .138 | 771 | | --- | .140 | 767 | 1370(m) | --- |
| | 13 | .132 | 775 | | --- | .138 | 771 | 673 | .87 | .140 | 767 | 336(s) | --- |
| | 14 | .132 | 775 | 1184(m) | --- | .138 | 771 | 1429(m) | --- | .140 | 767 | 704 | .92 |
| NON-BOOSTER END | 15 | .132/.160 | 768 | | --- | .138/.160 | 768 | | --- | .140/.160 | 764 | 648 | .85 |
| ESTIMATED "K" FACTOR FOR DRAG IN FUEL | | | | | | | | | | | | | |

NOTE: (s) AFTER THE FRAGMENT WEIGHT MEANS THAT FRAGMENT SCABBED; (m) AFTER THE FRAGMENT MEANS THAT THE FRAGMENT WAS A MULTIPLE-FRAGMENT



FIGURE 311-17

## WEIGHTS OF RECOVERED FRAGMENTS
## TEST QN0311A0

| GROOVE-SPACING (circumferential) | | | 1-3/16-INCH (INSIDE) | | | |
|---|---|---|---|---|---|---|
| LONGITUDINAL GROOVE DEPTH | INSIDE | | 0.100-inch | | | |
| | OUTSIDE | | 0.100-inch | | | |
| | | FRAGMENT ROW | CIRCUMFERENTIAL GROOVE DEPTH (inch | THEORETICAL FRAGMENT WEIGHT (grains) | RECOVERED FRAGMENT WEIGHT (grains) | RECOVERED WEIGHT : THEORETICAL WEIGHT |
| BOOSTER END | | 1 | .160 / .127 | 1014 | 455(s) / 818 | -- / .81 |
| | | 2 | .127 | 1021 | --- | -- |
| | | 3 | .127 | 1021 | --- | -- |
| | | 4 | .127 | 1021 | --- | -- |
| | | 5 | .127 / .147 | 1015 | --- | -- |
| | | 6 | .147 | 1010 | 846 | .84 |
| | | 7 | .147 | 1010 | --- | -- |
| | | 8 | .147 | 1010 | 860 / 878 | .85 / |
| | | 9 | .147 | 1010 | 885 | .88 |
| | | 10 | .147 | 1010 | 895 | .89 |
| | | 11 | .147 | 1010 | --- | -- |
| | | 12 | .147 | 1010 | --- | -- |
| | | 13 | .147 | 1010 | --- | -- |
| | | 14 | .147 | 1010 | --- | -- |
| NON-BOOSTER END | | 15 | .147 / .160 | 1009 | --- | -- |
| ESTIMATED "K" FACTOR FOR DRAG IN FUEL | | | | | | |

NOTE: (s) AFTER THE FRAGMENT WEIGHT MEANS THAT FRAGMENT SCABBED; (m) AFTER THE FRAGMENT MEANS THAT THE FRAGMENT WAS A MULTIPLE-FRAGMENT



FIGURE 311-18

TEST QN0319A0
8", 80-LB PREFORMED-FRAGMENT WARHEAD

## 2.1.4 TEST 3, QN0319A0

### 2.1.4.1 DESIGN SUMMARY AND RATIONALE

The basic design characteristics of the warhead (Figures 319-1 and 319-2) were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 8.0-inch |
| INSIDE DIAMETER: | 2.0-inch |
| LENGTH: | 15.2-inch |
| CASE THICKNESS: | 0.445-inch |
| FRAGMENT TYPE: | Pre-formed Hex HIBAL |
| FRAGMENT THICKNESS: | 0.420-inch |
| SKIN THICKNESS: | 0.025-inch |
| FRAGMENT MATERIAL: | SAE 4130, (RC-42) |
| SKIN MATERIAL: | Mild Steel |
| WARHEAD WEIGHT: | 80-lb |
| SHROUD: | 0.050-inch titanium with 1-inch urethane foam insulation |

Three choices of preformed hex-HIBAL fragments were used; 7/8-inch across flats by 0.42-inch thick (500-grains), 1-inch across flats by 0.42-inch thick (700-grains) and 1-1/8-inch across flats by 0.42-inch thick (900-grains). The case thickness/length combination was designed to achieve fragment velocities of 5000-, 5500-ft/sec after passing through the shroud. Only an outside skin (0.025-inch steel) was used, and 7/16" x 1/2" hoops at each end provided for rigidity. The fragments were potted in laminac. The shroud (Figure 319-3) is the same design as for the 8-inch fireformed-fragment warhead.

### 2.1.4.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENAS

The objectives of the test were to measure fragment velocities and polar ejection angles, and to recover the hex-HIBAL fragments, for determining the detonation and/or the shroud effects on the resulting fragment quality. The test arena plan is in Figure 319-6 and photographs of the test arena, are in Figures 319-12 and 319-13.

### 2.1.4.3 DESCRIPTION OF TEST RESULTS

A. <u>Fragment Quality</u>

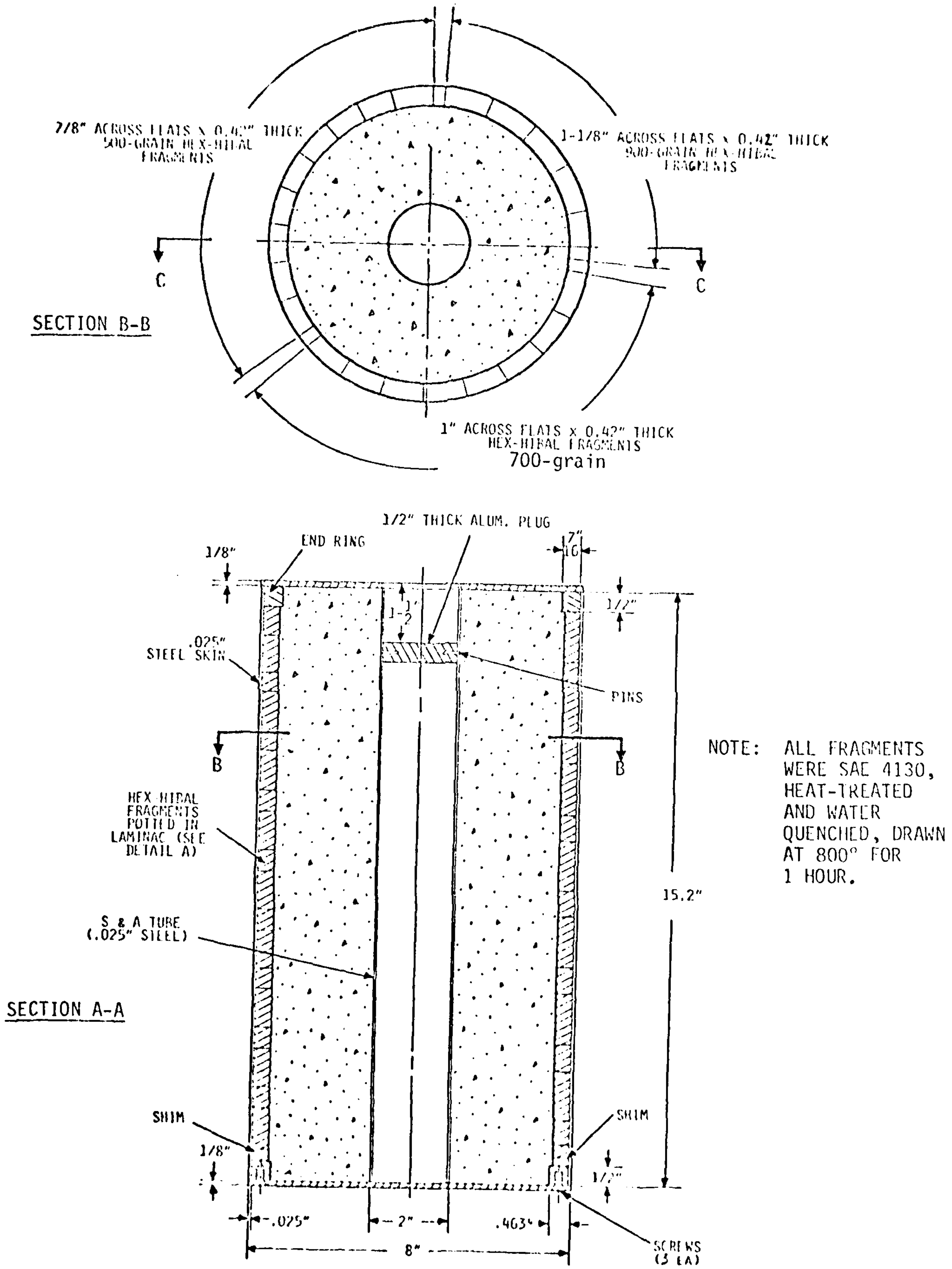
The recovered fragments exhibited minor deformation resulting from the detonation-wave sweep, but showed no loss in weight (Figure 319-5).

## B. Fragment Pattern and Velocity

The fragment polar-ejection-angle, as a function of the fragment center-of-length distance from the booster end of the warhead, is presented in Figure 319-7. A summary table of the fragment polar-ejection-angles and velocities is presented in Figure 319-8. Fragment-hit-location measurements are presented in Figures 319-9 through 319-11. Photographs of the fragment pattern on the witness sheets are presented in Figures 319-14 and 319-15.

## C. Conclusions

There is no need for further 8-inch diameter, 80-lb preformed fragment warhead tests. The recovered fragments were satisfactory in terms of fragment shape and weight, and the pattern and velocity data were adequate to formulate warhead characterization models for the second phase end game analysis.

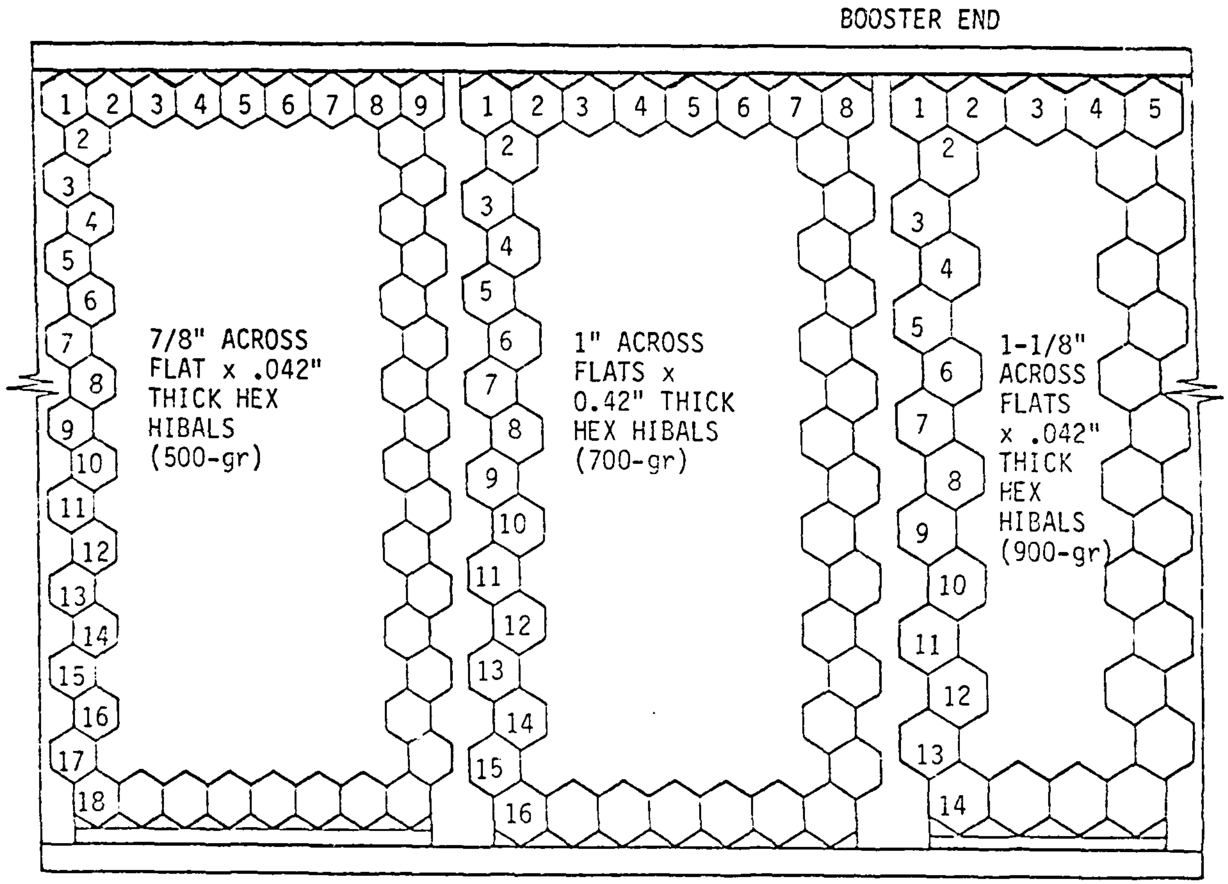



NOTE: ALL FRAGMENTS WERE SAE 4130, HEAT-TREATED AND WATER QUENCHED, DRAWN AT 800° FOR 1 HOUR.

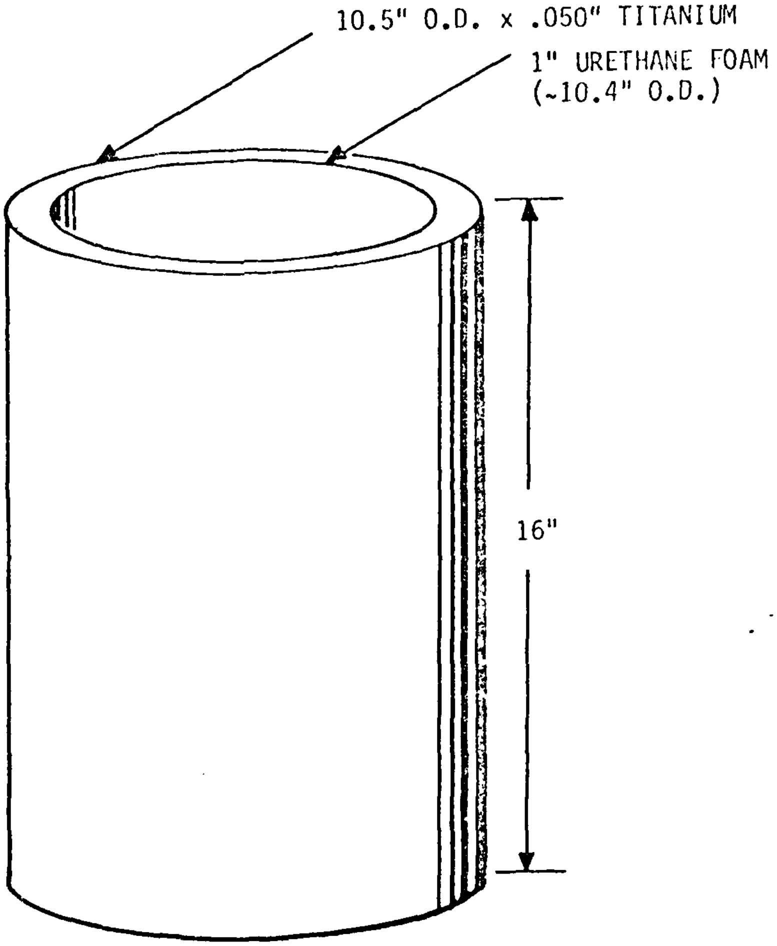
80-LB PREFORMED HEX-HIBAL WARHEAD
TEST 0N0319A0

FIGURE 319-1

DETAIL A




OUTSIDE VIEW OF FRAGMENT PACKAGE
TEST QN0319A0



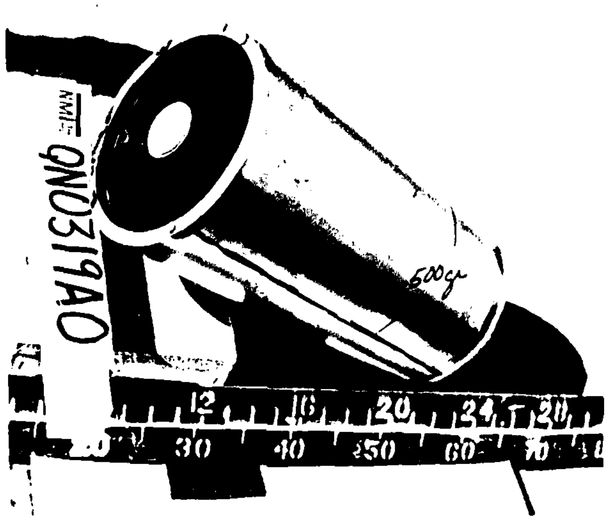

SHROUD FOR 8" O.D., 80-LB WARHEAD

TEST QN0319A0



FIGURE 319-3

TEST: QN0319A9




VIEWS OF WARHEAD WITHOUT C-4

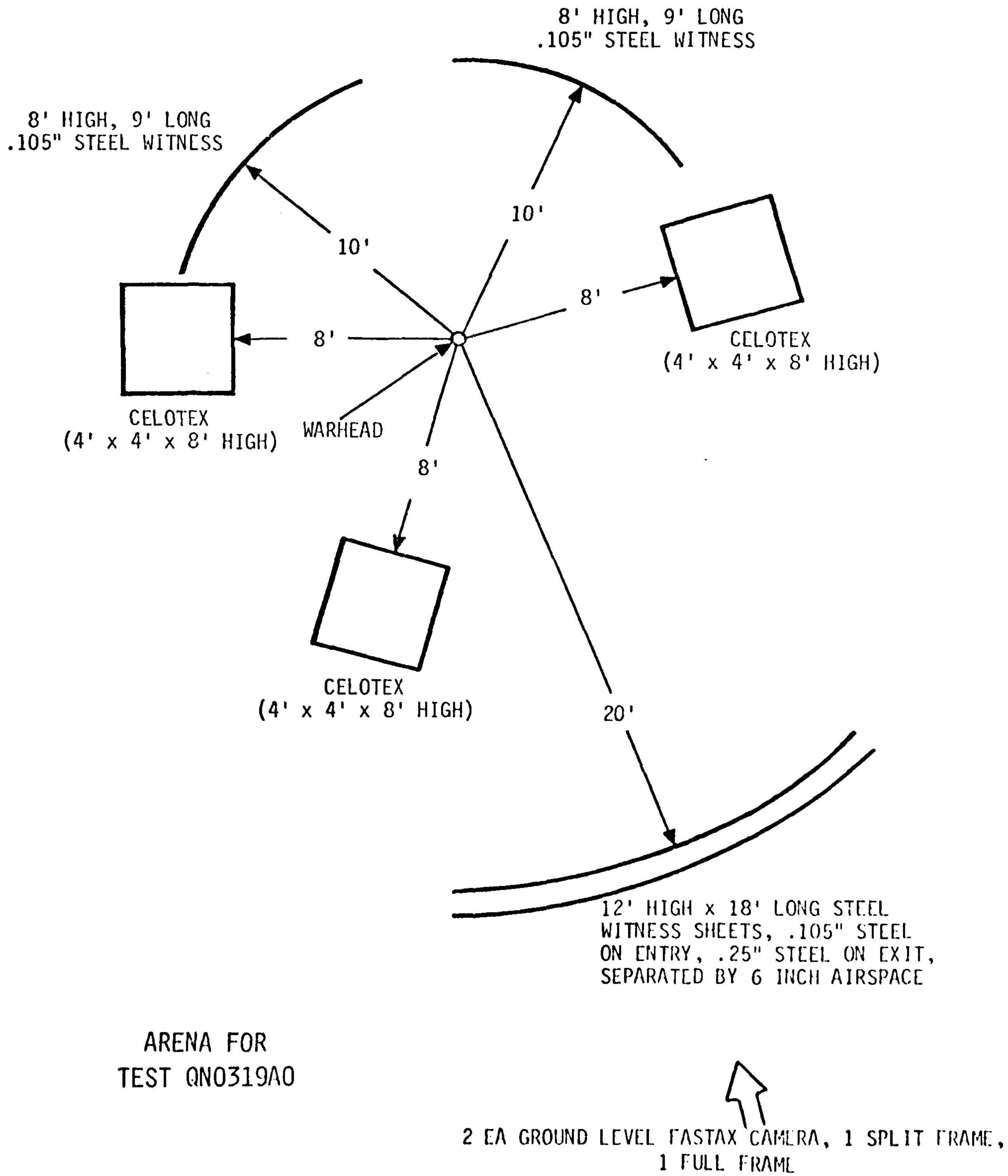



FIGURE 319-4


TYPICAL 500 GRAIN HEX HIBAL FRAGMENTS RECOVERED
IN TEST QN0319A0



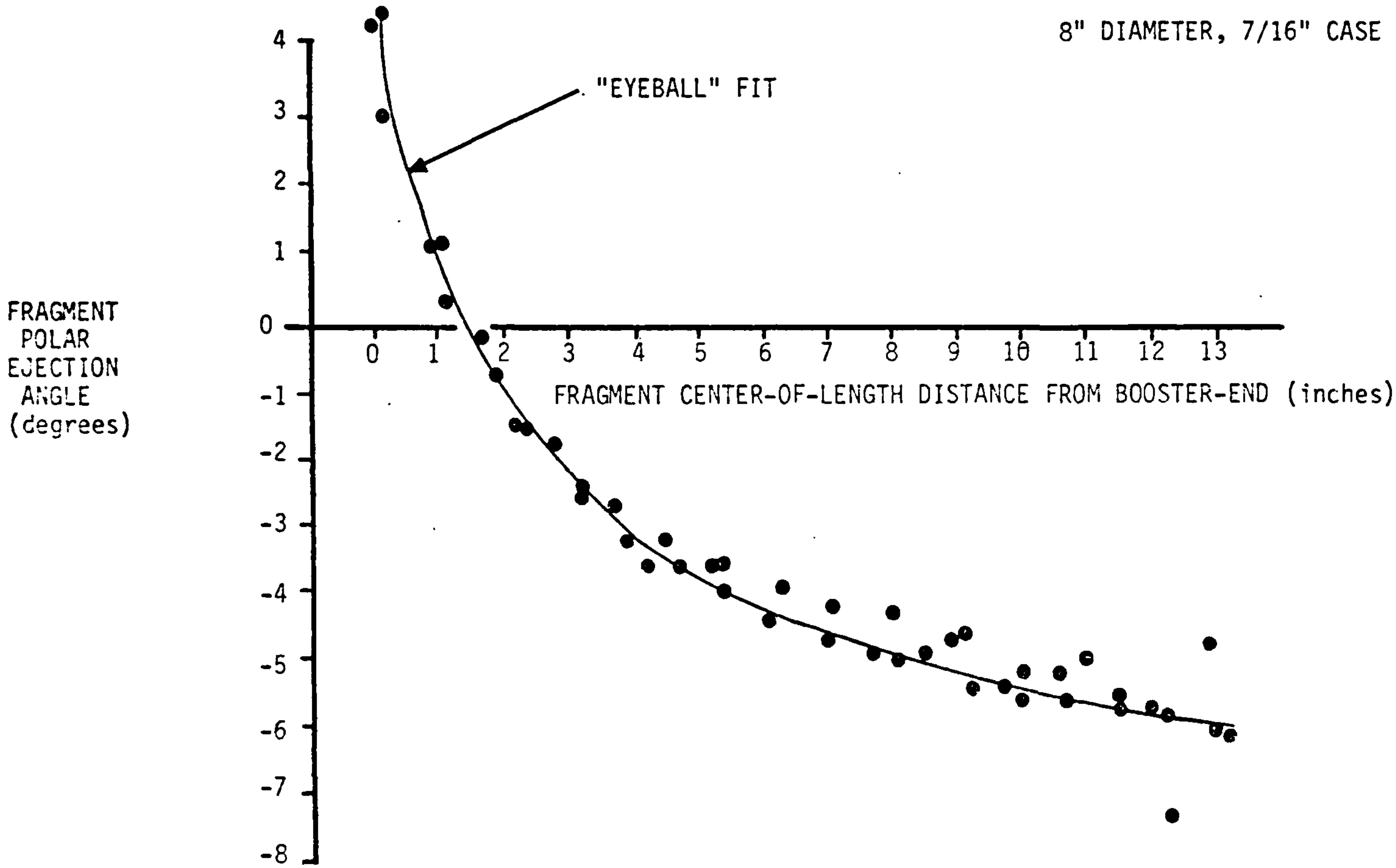
FIGURE 319-5




ARENA FOR
TEST QN0319A0



FIGURE 319-6




FRAGMENT POLAR EJECTION ANGLE AS A FUNCTION OF THE FRAGMENT CENTER-OF-LENGTH DISTANCE FROM THE BOOSTER END OF THE WARHEAD, TEST QN0319AO



FIGURE 319-7

TEST QN0319A0

SUMMARY OF POLAR EJECTION ANGLE AND VELOCITY RESULTS

| FRAGMENT ROW | FRAG. C.G. DIST. * FROM BOOSTER-END | POLAR ANGLE (DEGREES) | | | POLAR ANGLE SUMMARY | AVERAGE VELOCITY (0-20') ** |
|---|---|---|---|---|---|---|
| | | 500-GR | 700-GR | 900-GR | | |
| 1 | 1.1 (5) | +4.5 | | | 4.5 | 4210 |
| 1 | 1.2 (7) | | +4.7 | | 4.7 | |
| 1 | 1.3 (9) | | | +3.2 | 3.2 | |
| 2 | 1.9 (5) | +1.2 | | | 1.2 | 4670 |
| 2 | 2.1 (7) | | +1.2 | | 1.2 | |
| 2 | 2.2 (9) | | | +0.4 | 0.4 | |
| 3 | 2.7 (5) | -0.2 | | | -0.2 | 5000 |
| 3 | 2.9 (7) | | -0.7 | | -0.7 | |
| 3 | 3.2 (9) | | | -1.5 | -1.5 | |
| 4 | 3.4 (5) | -1.6 | | | -1.6 | 5080 |
| 4 | 3.8 (7) | | -1.8 | | -1.8 | |
| 4 | 4.2 (9) | | | -2.5 | -2.5 | |
| 5 | 4.2 (5) | -2.6 | | | -2.6 | 5380 |
| 5 | 4.7 (7) | | -2.7 | | -2.7 | |
| 6 | 4.9 (5) | -3.2 | | | -3.2 | 5400 |
| 5 | 5.2 (9) | | | -3.6 | -3.6 | |
| 6 | 5.5 (7) | | -3.2 | | -3.2 | |
| 7 | 5.7 (5) | -3.6 | | | -3.6 | 5470 |
| 6 | 6.2 (9) | | | -3.6 | -3.6 | |
| 7 | 6.4 (7) | | -3.6 | | -3.6 | |
| 8 | 6.4 (5) | -4.0 | | | -4.0 | 5490 |
| 7 | 7.1 (9) | | | -4.4 | -4.4 | |
| 9 | 7.2 (5) | -4.3 | | | -4.3 | 5470 |
| 8 | 7.3 (7) | | -3.9 | | -3.9 | |
| 10 | 8.0 (5) | -4.7 | | | -4.7 | 5580 |
| 9 | 8.1 (7) | | -4.2 | | -4.2 | |
| 8 | 8.1 (9) | | | -4.2 | -4.2 | |
| 11 | 8.7 (5) | -4.9 | | | -4.9 | 5660 |
| 10 | 9.0 (7) | | -4.3 | | -4.3 | |
| 9 | 9.1 (9) | | | -5.0 | -5.0 | |
| 12 | 9.5 (5) | -4.9 | | | -4.9 | 5630 |
| 11 | 9.9 (7) | | -4.7 | | -4.7 | |
| 10 | 10.1 (9) | | | -4.6 | -4.6 | |
| 13 | 10.2 (5) | -5.4 | | | -5.4 | 5690 |
| 12 | 10.7 (7) | | -5.4 | | -5.4 | |
| 14 | 11.0 (5) | -5.6 | | | -5.6 | 5580 |
| 11 | 11.0 (9) | | | -5.2 | -5.2 | |
| 13 | 11.6 (7) | | -5.2 | | -5.2 | |
| 15 | 11.7 (5) | -5.6 | | | -5.6 | 5660 |
| 12 | 12.0 (9) | | | -5.0 | -5.0 | |
| 16 | 12.5 (5) | -5.6 | | | -5.6 | 5490 |
| 14 | 12.5 (7) | | -5.7 | | -5.7 | |
| 13 | 13.0 (9) | | | -5.7 | -5.7 | |
| 15 | 13.3 (7) | | -5.8 | | -5.8 | |
| 17 | 13.3 (5) | -7.3 | | | -7.3 | 5570 |
| 14 | 13.9 (9) | | | -4.8 | -4.8 | |
| 18 | 14.0 (5) | -6.0 | | | -6.0 | 5490 |
| 16 | 14.2 (7) | | -6.1 | | -6.1 | |

* DISTANCE INCLUDES END PLATE AND THROW AWAY RING

** VELOCITY RESULTS ARE FROM THE 500-gr DATA SECTOR, AND ARE THE AVERAGE OF THREE FRAGMENT HITS FOR EACH FRAGMENT ROW



FIGURE 319-8

# 500-GR FRAGMENT POLAR EJECTION ANGLES, TEST QN0319A0

| FRAGMENT ROW | DIST. FROM TOP OF W.H. (INCHES) | FRAGMENT HIT LOCATIONS RELATIVE TO TOP OF W.H. 1 AT 19'9" | 2 AT 19'6" | 3 AT 19'3" | 4 AT 19'11" | 5 AT 20'3" | 6 AT 20'7" | 7 AT 19'5" | 8 AT 19'2" | POLAR EJECTION ANGLE (DEGREES) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | AVG. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.13 | +19.5 | | +15 | | +16-1/2 | | 20 | | 5.0 | | 3.9 | | 4.1 | | +4.9 | | 4.5 |
| 2 | 1.89 | | +5 | | +3-1/2 | | 0 | | +4 | | +1.7 | | +1.3 | | +.4 | | +1.5 | 1.2 |
| 3 | 2.65 | -3.5 | | -2.5 | | -1 | | -3 | | -0.2 | | 0.0 | | -.4 | | -.1 | | -0.2 |
| 4 | 3.43 | | -9 | | -10 | | -11-1/2 | | -11 | | -1.1 | | -1.6 | | -1.9 | | -1.9 | -1.6 |
| 5 | 4.16 | -15 | | -15 | | -15-1/2 | | -13-1/2 | | -2.6 | | -2.6 | | -2.7 | | -2.3 | | -2.6 |
| 6 | 4.92 | | -16 | | -16 | | -20-1/2 | | -20-1/2 | | -2.7 | | -2.7 | | -3.6 | | -3.9 | -3.2 |
| 7 | 5.63 | -19 | | -18 | | -23 | | -23-1/2 | | -3.2 | | -3.0 | | -4.1 | | -3.9 | | -3.6 |
| 8 | 6.44 | | -21 | | -25 | | -24-1/2 | | -21 | | -3.6 | | -4.4 | | -4.2 | | -3.6 | -4.0 |
| 9 | 7.19 | -26 | | -23 | | -26-1/2 | | -25-1/2 | | -4.5 | | -3.9 | | -4.5 | | -4.5 | | -4.3 |
| 10 | 7.95 | | -26.5 | | -28-1/2 | | -27 | | -27 | | -4.5 | | -5.0 | | -4.4 | | -4.7 | -4.7 |
| 11 | 8.71 | -29 | | -28.5 | | -29-1/2 | | -29-1/2 | | -4.8 | | -4.8 | | -4.9 | | -5.1 | | -4.9 |
| 12 | 9.47 | | -28.5 | | -30-1/2 | | -32 | | -28 | | -4.6 | | -5.0 | | -5.2 | | -4.6 | -4.9 |
| 13 | 10.22 | -33 | | -33.5 | | -31 | | -33 | | -5.5 | | -5.6 | | -4.9 | | -5.6 | | -5.4 |
| 14 | 11.00 | | -32 | | -36-1/2 | | -36-1/2 | | -32 | | -5.1 | | -6.1 | | -5.9 | | -5.2 | -5.6 |
| 15 | 11.74 | -34.5 | | -35 | | -34 | | -38-1/2 | | -5.5 | | -5.6 | | -5.2 | | -6.6 | | 5.7 |
| 16 | 12.5 | | -34 | | -37-1/4 | | -38-1/2 | | -33 | | -5.2 | | -5.9 | | -6.0 | | -5.1 | 5.6 |
| 17 | 13.26 | -40.5 | | -39 | | -44 | | -48-1/2 | | -7.0 | | -6.2 | | -7.2 | | -8.6 | | -7.3 |
| 18 | 14.0 | | -36 | | -41 | | -41-1/2 | | -36-1/2 | | -5.4 | | -6.5 | | -6.3 | | -5.6 | -6.0 |

NOTE: 8 COLUMNS OF FRAGMENTS HIT WITNESS SHEET.

700-GR FRAGMENTS - POLAR EJECTION ANGLES AT 10'

TEST QN0319A0

| FRAGMENT ROW | DIST. FROM TOP OF W.H. (INCHES) | FRAGMENT HIT LOCATION RELATIVE TO TOP OF H.W. | | | | | AVERAGE (INCHES) | NET SWEEP (INCHES) | POLAR EJECTION ANGLE |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | | |
| 1 | 1.2 | +8 | | +9-1/2 | | 8-1/2 | +8.7 | 9.9 | +4.7° |
| 2 | 2.1 | | 0 | | +1 | | +0.5 | 2.6 | +1.2° |
| 3 | 2.9 | -4-/12 | | -4-1/2 | | -4 | -4.3 | -1.4 | -0.7° |
| 4 | 3.8 | | -7-1/2 | | -7-1/2 | | -7-1/2 | -3.7 | -1.8° |
| 5 | 4.7 | -10 | | -10-1/2 | | -10-1/2 | -10.3 | -5.6 | -2.7° |
| 6 | 5.5 | | -12 | | -12-1/2 | | 12.25 | -6.8 | -3.2° |
| 7 | 6.4 | -13-1/2 | | -14-1/2 | | -14 | -14 | -7.6 | -3.6° |
| 8 | 7.3 | | -15-1/2 | | -15-1/5 | | -15-1/2 | -8.2 | -3.9° |
| 9 | 8.1 | -16-1/2 | | -17-1/2 | | -17 | -17 | -8.9 | -4.2° |
| 10 | 9.0 | | -18 | | -18 | | -18 | -9.0 | -4.3° |
| 11 | 9.9 | -19 | | -20-1/2 | | -20 | -19.8 | -9.9 | -4.7° |
| 12 | 10.7 | | -22-1/2 | | -21-1/2 | | -22 | -11.3 | -5.4° |
| 13 | 11.6 | -22 | | -23-1/2 | | -22 | -22-1/2 | -10.9 | -5.2° |
| 14 | 12.5 | | -24 | | -25 | | -24-1/2 | -12.0 | -5.7° |
| 15 | 13.3 | -25 | | -26 | | -25-1/2 | -25-1/2 | -12.2 | -5.8° |
| 16 | 14.2 | | -27 | | | | -27 | -12.8 | -6.1° |

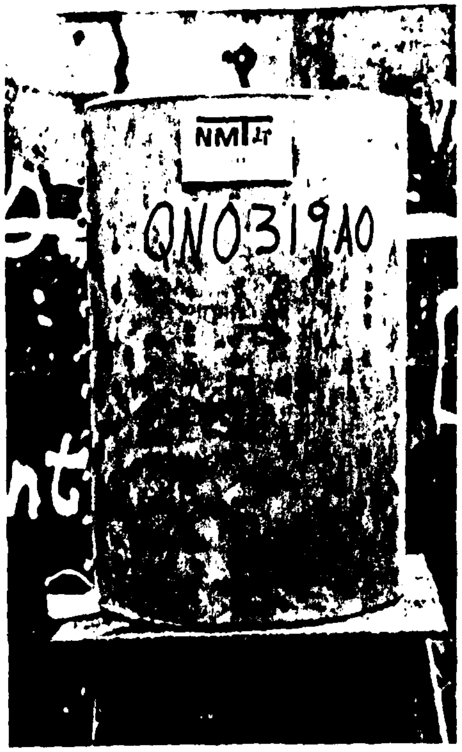


FIGURE 319-10

## 900-GR POLAR EJECTION ANGLES, TEST QN0319A0

| FRAGMENT ROW | DIST. FROM TOP OF W.H. (INCHES) | FRAGMENT HIT LOCATION RELATIVE TO TOP OF W.H. AT 10' | | | | | AVERAGE (INCHES) | NET SWEEP (INCHES) | POLAR EJECTION ANGLE |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | | | |
| 1 | 1.28 | +6-1/2 | | +6 | | +4 | +5.5 | +6.78 | +3.2° |
| 2 | 2.25 | | -1-1/2 | | -1-1/2 | | -1.5 | + .75 | +0.4° |
| 3 | 3.22 | -5-1/2 | | -5-1/2 | | -8 | -6.3 | -3.08 | -1.5° |
| 4 | 4.20 | | -10 | | -9 | | -9-1/2 | -5.3 | -2.5° |
| 5 | 5.17 | -12 | | -11-1/2 | | -14-1/2 | -12.7 | -7.53 | -3.5° |
| 6 | 6.15 | | -14-1/2 | | -13 | | -13.75 | -7.6 | -3.6° |
| 7 | 7.12 | -18 | | -14-1/2 | | 16.75 | -16.4 | -9.28 | -4.4° |
| 8 | 8.10 | | -17-1/2 | | -16-1/2 | | -17.0 | -8.9 | -4.2° |
| 9 | 9.07 | -22 | | -17-1/2 | | 19 | 19-1/2 | -10.43 | -5.0° |
| 10 | 10.05 | | -21-1/2 | | -18 | | 19.75 | -9.7 | -4.6° |
| 11 | 11.02 | -23 | | -21 | | 21.75 | 21.9 | -10.88 | -5.2° |
| 12 | 12.00 | | -23-1/2 | | -21-1/2 | | 22.5 | -10.5 | -5.0° |
| 13 | 12.97 | -26 | | -25-1/2 | | -23-1/2 | 25.0 | 12.03 | -5.7° |
| 14 | 13.94 | | -24-1/2 | | -23-1/2 | | 24.0 | 10.06 | -4.8° |

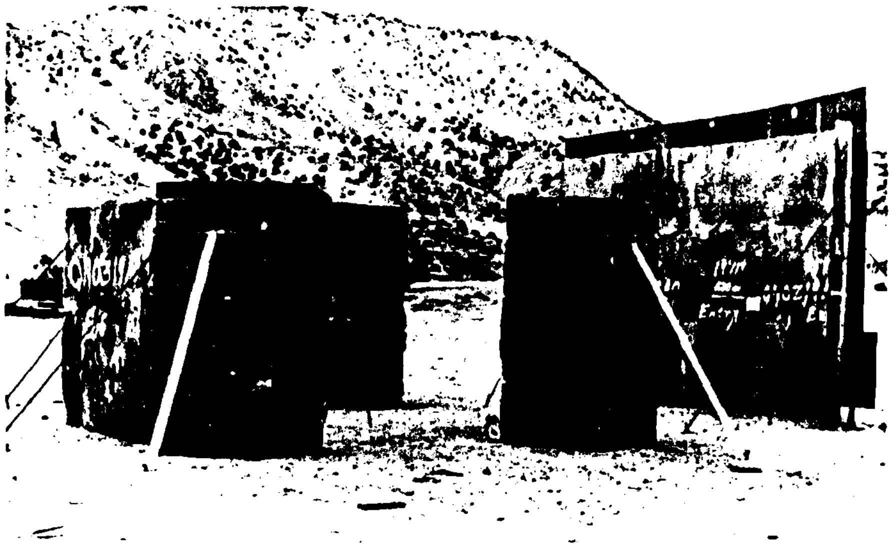

WARHEAD IN PLACE IN TEST ARENA
WITH SHROUD REMOVED




WARHEAD IN PLACE IN TEST ARENA
WITH SHROUD INSTALLED



FIGURE 319-12



VIEWS OF THE TEST ARENA BEFORE DETONATION




FIGURE 319-13


WITNESS SHEET AFTER TEST; 700gr FRAGMENTS;
ENTRY SIDE; 10' RADIUS

WITNESS SHEET AFTER TEST; 900gr FRAGMENTS;
ENTRY SIDE; 10' RADIUS



FIGURE 319-14

WITNESS SHEET AFTER TEST; 500gr FRAGMENTS:
ENTRY SIDE; 20' RADIUS

TEST QN0328A0

11.5", 200-LB FIREFORMED FRAGMENT WARHEAD

## 2.1.5 TEST 4, QN0328A0

### 2.1.5.1 DESIGN SUMMARY AND RATIONALE

The basic design characteristics of the warhead (Figures 328-1 and 328-2) were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 11.5-inch |
| INSIDE DIAMETER: | 2.875-inch |
| LENGTH: | 18.375-inch |
| CASE THICKNESS: | 0.563-inch |
| CASE MATERIAL: | SAE 4140, (RC37-42) |
| FRAGMENT TYPE: | Fireformed |
| WARHEAD WEIGHT: | 200-lb |
| SHROUD: | Double walled steel, 0.020-inch inside, 0.030" outside, plus 1-inch urethane foam insulation between warhead and shroud |

The fragment case was grooved circumferentially to provide 19 rows of equal length fragments, each 0.888-inch long. The spacing between the longitudinal grooves was varied to determine if the spacing significantly affected fragment quality. The (external) spacings tested were 0.675-, 0.866- and 1.108-inch. The fragment weights for these spacings would be 600-, 770-, and 990-grains respectively (with no loss in the fireforming). The shroud (Figure 328-3) tested was identical to that of the previous 11-1/2-inch-diameter warhead.

The "best" opposed groove designs from test QN0311A0 indicated that shallower groove depths were required for fragments located near the booster end of the warhead, than for fragments located near the non-booster end. This was true for both longitudinal and circumferential grooves.

A. Longitudinal Grooves

The longitudinal grooves were tapered in depth, from one end of the warhead to the other. The tapering of the longitudinal grooves was based on the depths of the "best" opposed groove designs from test QN0311A0, and ratioed to account for the increase in case thickness from 0.5 to 0.5625-inch. Calculations are presented below:

For Booster End:

use same ratio as in 0.100-inch deep grooves of QN0311A0.

$\left[\frac{0.200}{0.500} = \frac{x}{0.5625}\right.$; x = 0.225 total depth, or 0.113-inch deep inside and outside$\left.\right]$

For Non-Booster End:

use same ratio as in 0.130-inch deep grooves of QN0311A0.

$\left[\frac{0.260}{0.500} = \frac{x}{0.5625}\right.$; x = 0.293-inch total depth, or 0.146-inch inside and outside$\left.\right]$

The longitudinal grooves were tapered in two styles; one with the inside and outside grooves symmetrical, and one with only the outside groove tapered in depth, the inside groove remaining a constant depth. See figure 328-2.

## B. Circumferential Grooves

The circumferential grooves were uniformly increased in depth, from the booster end of the warhead. The "best" circumferential groove depths from test QN0311A0 were used as a basis, the depths being increased by the ratio of the case thicknesses. Calculations are presented below:

For Booster End:

use same ratio as in 0.100-inch deep grooves of QN0311A0, for first 7 rows. $\left[\frac{0.260}{0.500} = \frac{x}{0.5625}\right.$; x = 0.2925-inch total depth, or 0.146-inch inside and outside$\left.\right]$; for rows 8, 9, 10 $\left[\frac{0.300}{0.500} = \frac{x}{0.5625}\right.$; x = 0.3375-inch total depth, or 0.169-inch inside and outside$\left.\right]$

For Non-Booster End:

grooves calculate same ratio as in 0.130-inch deep grooves of QN0311A0. $\left[\frac{0.316}{0.500} = \frac{x}{0.5625}\right.$; x = 0.356-inch total depth, or 0.178-inch deep inside and outside$\left.\right]$; use 0.190-inch because of 18-inch length instead of the 15-inch length in QN0311A0.

## C. Booster-End Fragments

The first row of fragments on the booster end of the warhead were tapered, in an attempt to stop the fragment scabbing problems which occurred in the previous test. The fragments were therefore made somewhat longer to compensate for the weight lost in tapering.

2.1.5.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENA

The test objectives were to recover a sample of fragments from each of the parametric choices in groove design, and to measure fragment polar-ejection-angles and velocities. The test arena details are shown in Figure 328-8. Photographs of the test arena are shown in Figure 328-11.

2.1.5.3 DESCRIPTION OF TEST RESULTS

A. Fragment Quality

1. Longitudinal Grooves

The longitudinal grooves were of inadequate depth, and the results (of poor-quality fragments) typified by too much metal remaining between the apexes of the inside and outside grooves occurred in this test, including a significant amount of scabbing of the fragment. Figure 328-14 shows examples of the fragments having the deepest longitudinal grooves (i.e. the thinnest metal remaining between opposed grooves).

2. Circumferential Grooves

Numerous fragment lengthwise pairs were recovered, indicating that the total metal remaining between the apexes of the inside and outside circumferential grooves was too thick. Where the inside grooves exceeded 0.120-inch depth the non-booster-end inside-corners broke off as illustrated in Figure 328-11.

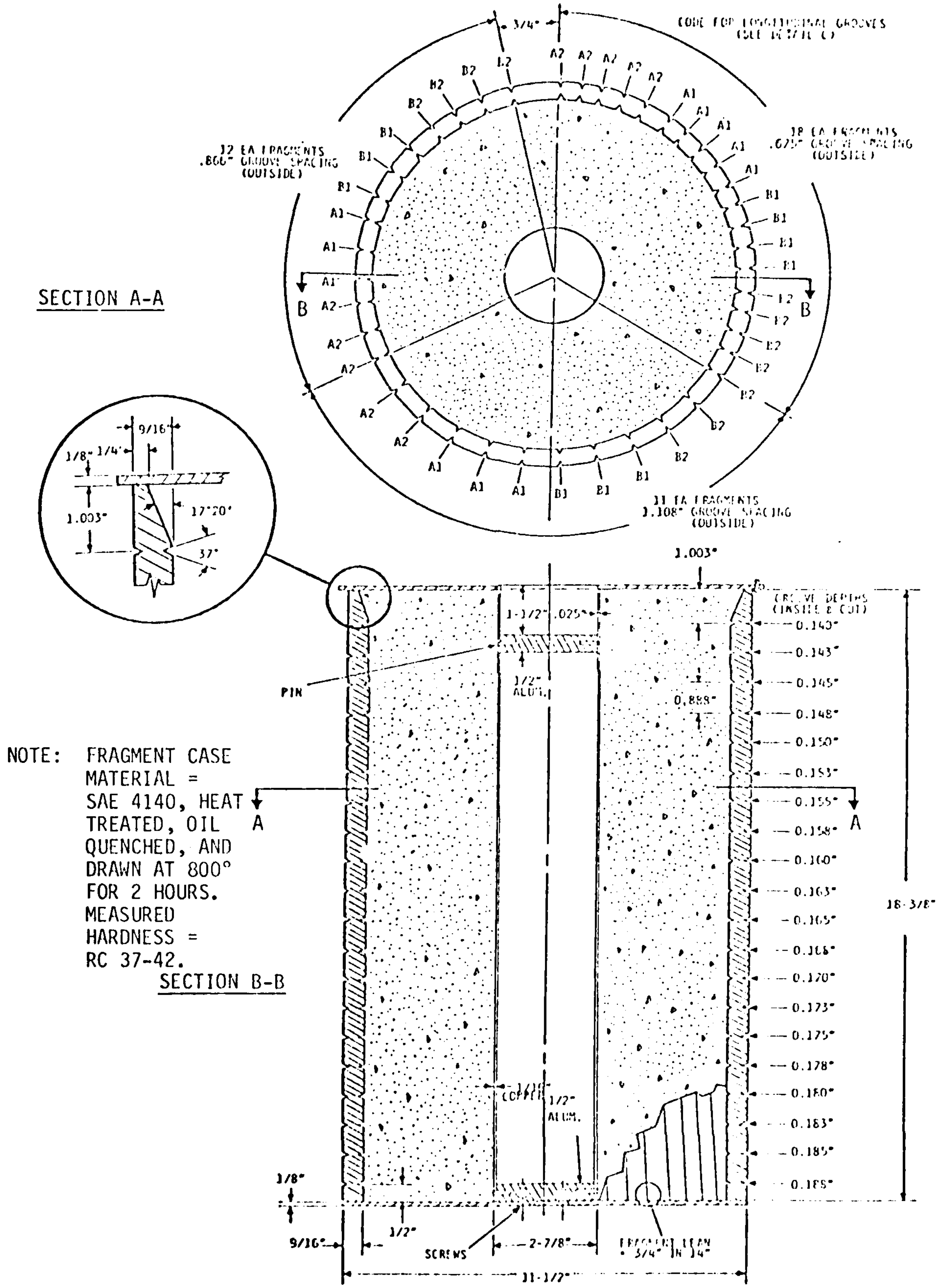
B. Fragment Velocity and Polar-Angle Characterization

The measurements of the fragment-hit locations are presented on pages 328-11 and 328-12, but polar-ejection-angles and detailed fragment velocities are not presented because the fragment lengthwise pairings and fragment scabs make identification of the primary fragments difficult. The velocities of the fragments ranged from 5700-ft/sec at the center-of-length of the warhead to 4900-ft/sec at the ends of the warhead.

C. Conclusions

1. The warhead design will have to be altered to achieve proper fireforming of fragments.

2. Change the design approach to consider metal remaining between the apexes of the opposed-grooves.




11-1/2" O.D., 200-LB FIRE-FORMED HIBAL WARHEAD

TEST QN0328A0

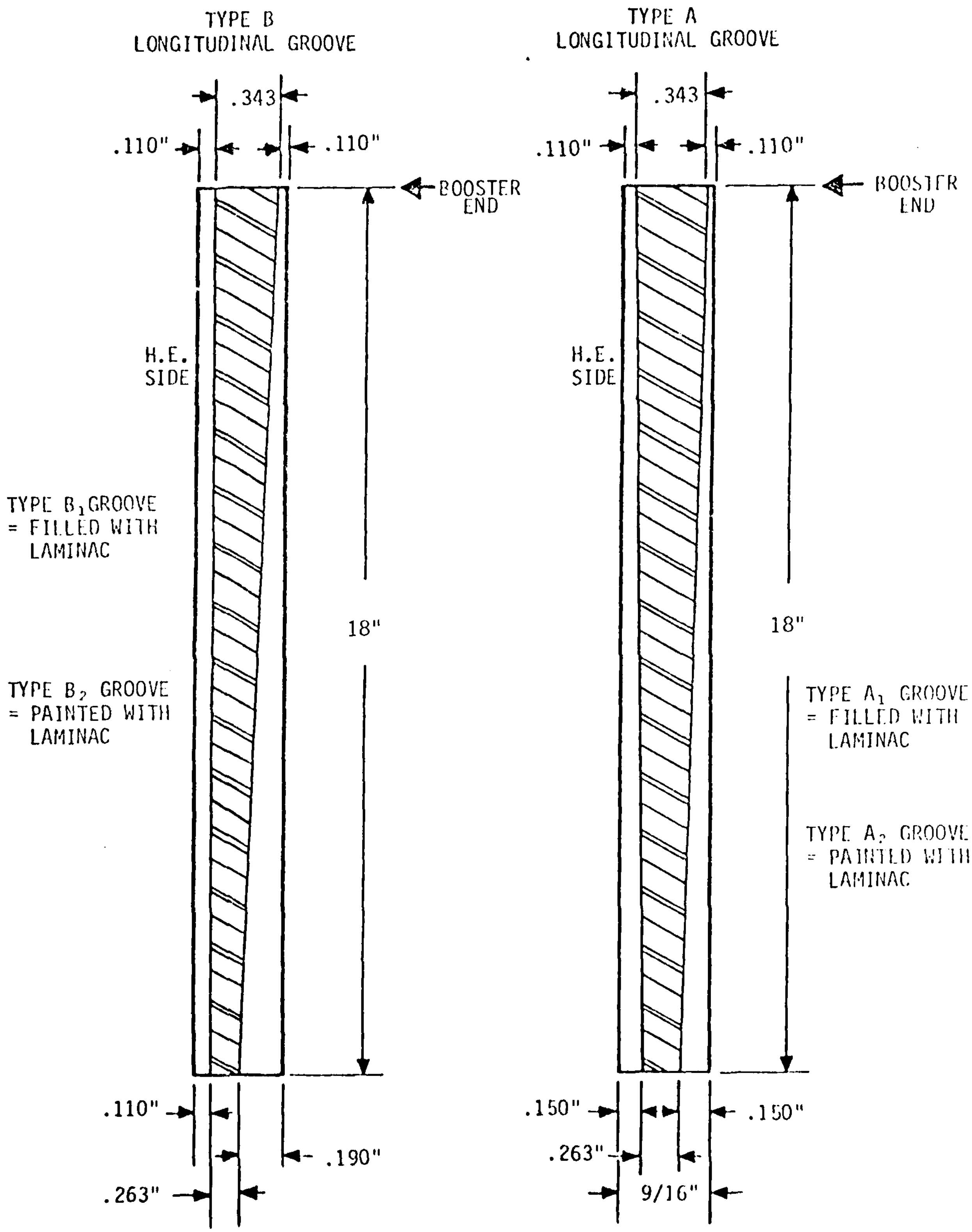
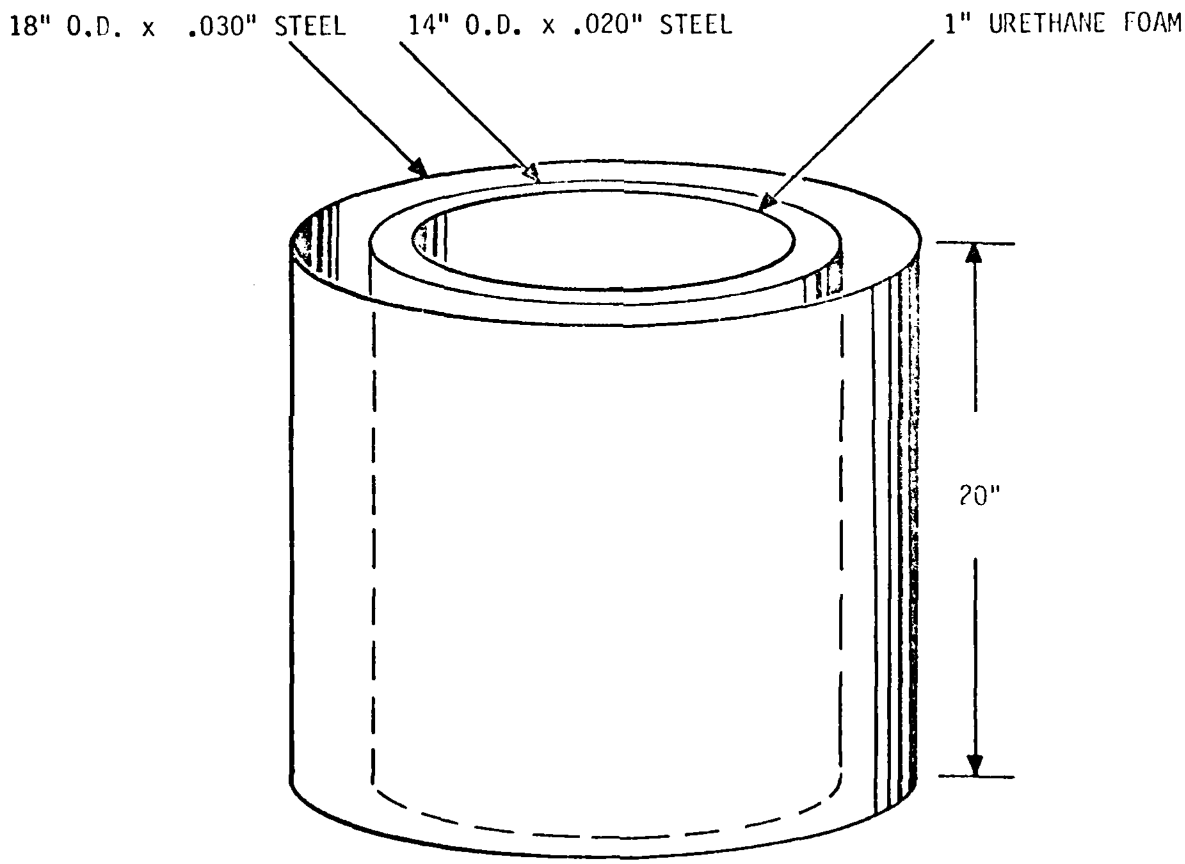

TYPE B
LONGITUDINAL GROOVE
.343
.110"
.110"
BOOSTER END
H.E. SIDE
TYPE B₁ GROOVE = FILLED WITH LAMINAC
TYPE B₂ GROOVE = PAINTED WITH LAMINAC
18"
.110"
.190"
.263"
TYPE A
LONGITUDINAL GROOVE
.343
.110"
.110"
BOOSTER END
H.E. SIDE
18"
TYPE A₁ GROOVE = FILLED WITH LAMINAC
TYPE A₂ GROOVE = PAINTED WITH LAMINAC
.150"
.150"
.263"
9/16"



FIGURE 328-2

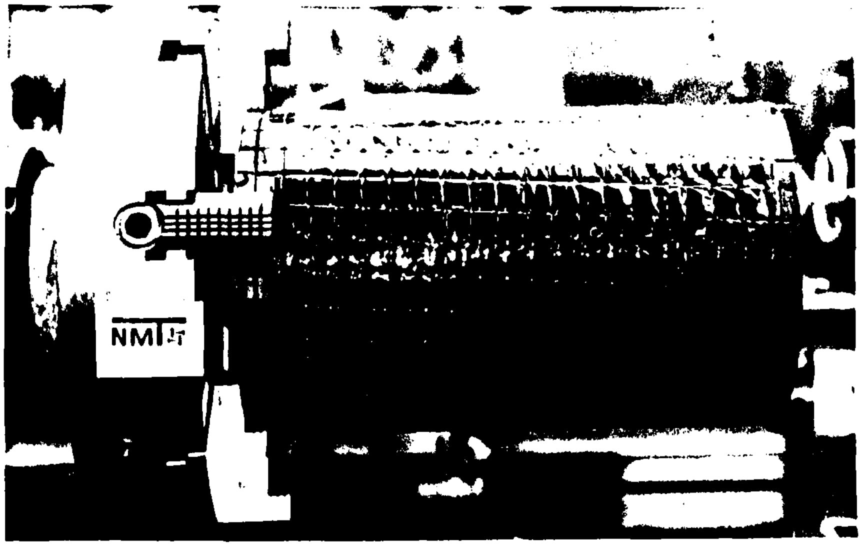



SHROUD FOR 11-1/2" O.D. 200-LB WARHEAD

TEST QN0328A0



FIGURE 328-3



WARHEAD ON LATHE DURING MANUFACTURE


COMPLETED UNLOADED WARHEAD
SHOWING EXTERIOR GROOVING



FIGURE 328-4


WARHEAD BEFORE BEING LOADED WITH EXPLOSIVE
SHOWING INTERIOR GROOVING

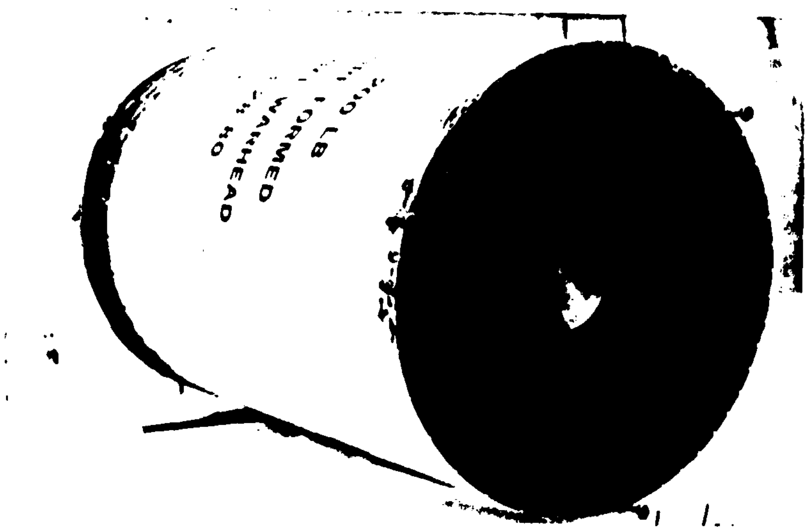
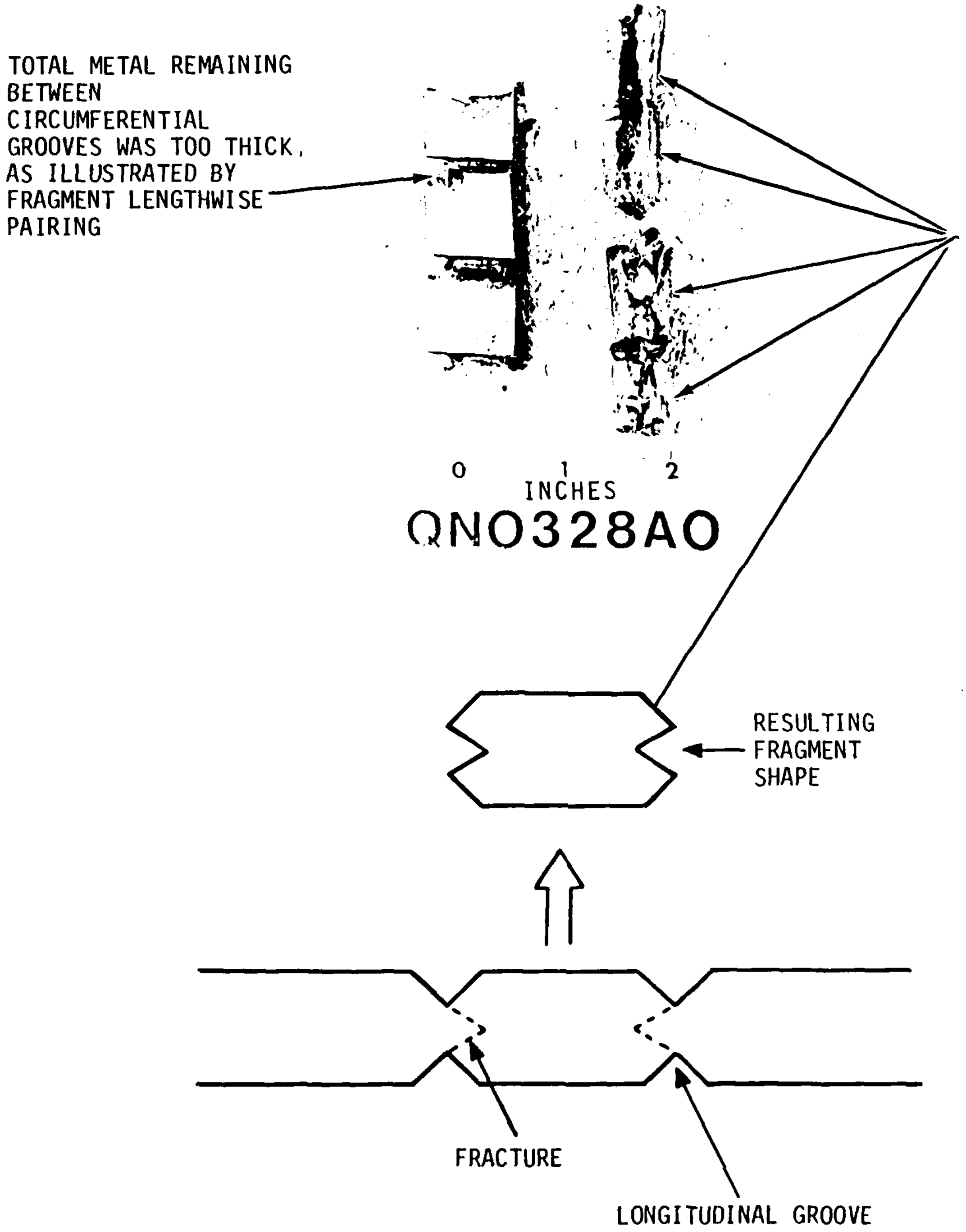




FIGURE 328-5




REDUCED-WEIGHT FRAGMENTS RESULTING WHEN THE METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.240" THROUGH 0.260"

EXAMPLE FRAGMENTS FROM TEST QN0328A0

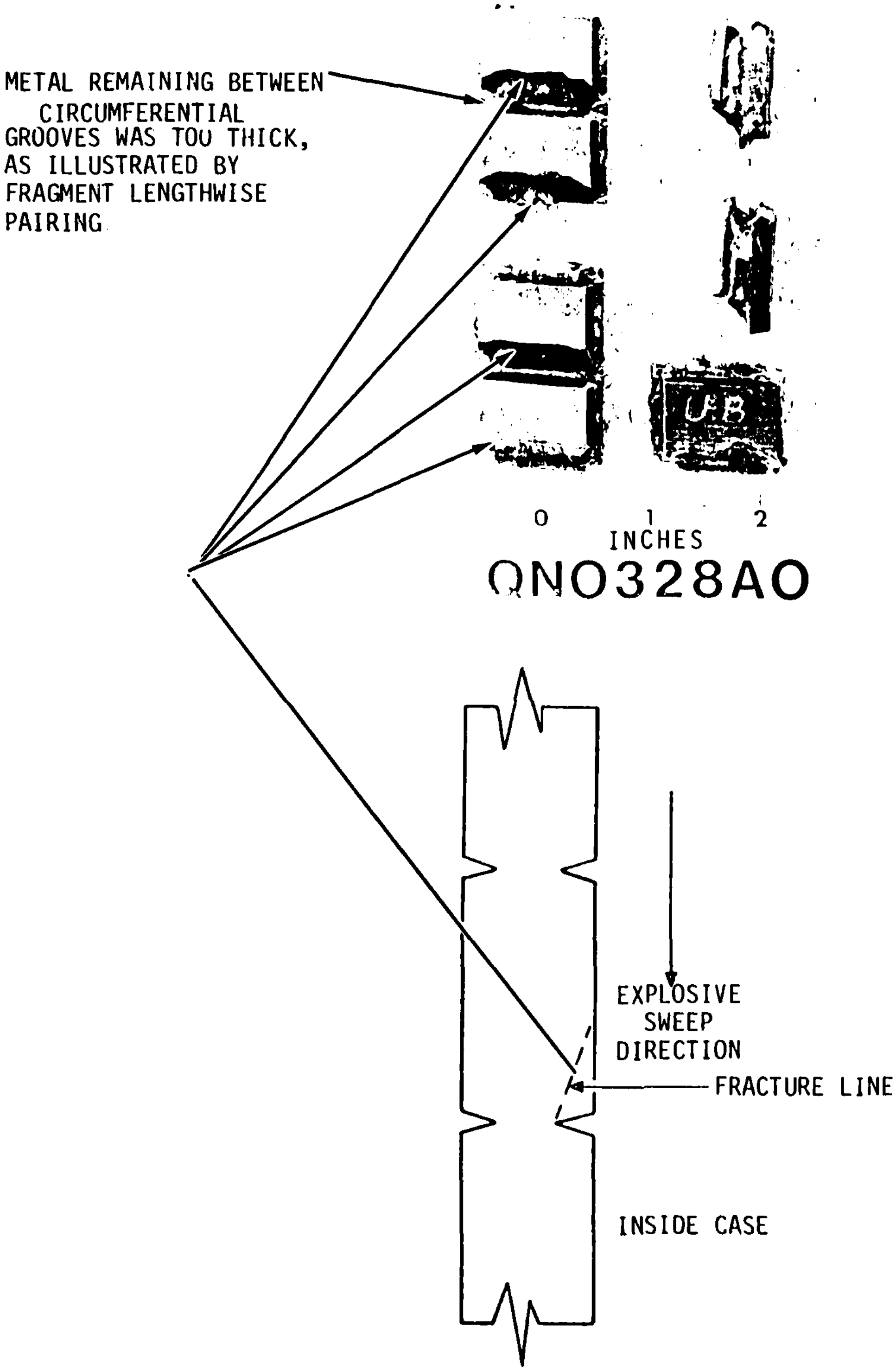
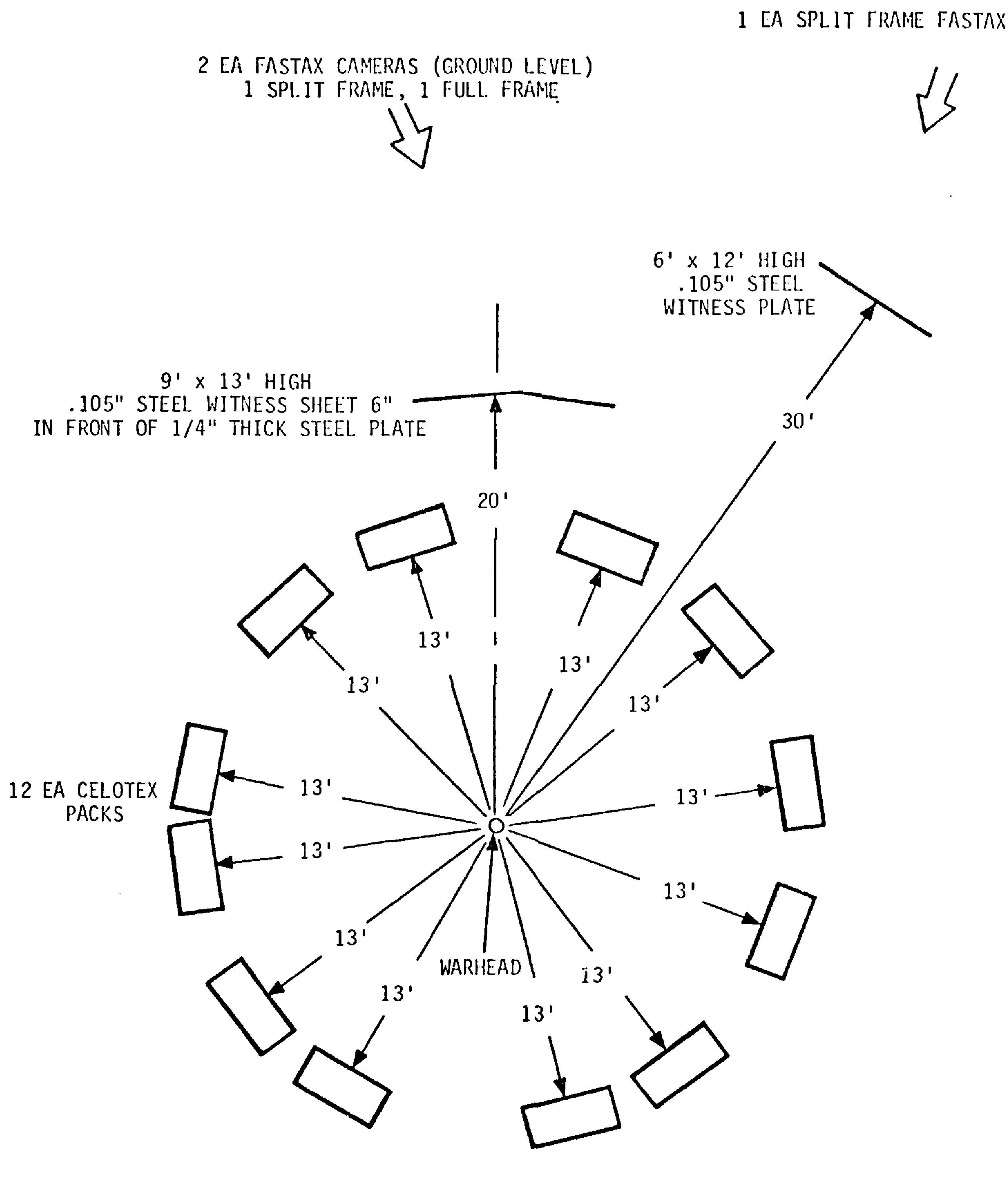



ILLUSTRATION SHOWING THE FRACTURE WHICH OCCURRED WHEN THE INSIDE CIRCUMFERENTIAL GROOVES EXCEEDED 0.120" DEPTH

EXAMPLE FRAGMENTS FROM TEST QN0328A0



FIGURE 328-7




TEST QN0328A0

11-1/2" O.D., 200-LB FIRE FORMED HIBAL WARHEAD

TEST QN0328A9

COORDINATES* OF FRAGMENT HIT LOCATIONS (INCHES)

ON THE WITNESS SHEETS

| FRAGMENT ROW NUMBER | 20' RADIUS WITNESS SHEET COORDINATES | | | |
|---|---|---|---|---|
| | COLUMN 1 | COLUMN 2 | COLUMN 3 | COLUMN 4 |
| 1 | -46-1/2 | +35 | +42 | +44 |
| 2 | -50 | +34 | +41 | +25-1/2 |
| 3 | -49 | +13 | +21 | +5 |
| 4 | -63-1/2 | +3.5 | +11 | -3-1/2 |
| 5 | | -5.5 | +8 | -11 |
| 6 | | -20** | -6 | -18-1/2 |
| 7 | | -28** | -22** | -22-1/2 |
| 8 | | -32-1/2** | -24 | -29** |
| 9 | | -32 | -29-1/2 | -34** |
| 10 | | -35 | -35 | -36** |
| 11 | | -38-1/2 | -34-1/2** | -41 |
| 12 | | -42-1/2** | -37 | -43 |
| 13 | | -36-1/2 | -43-1/2 | -44-1/2 |
| 14 | | -41 | -42 | -44 |
| 15 | | -42 | -46** | -45 |
| 16 | | -43 | -48 | -52 |
| 17 | | -45 | -48-1/2 | |
| 18 | | -46-1/2 | -45 | |
| 19 | | -48 | -48 | |
| 20 | | -63 | -49 | |
| 21 | | | -62-1/2 | |

* VERTICAL MEASUREMENTS ARE MEASURED FROM THE TOP OF THE WARHEAD AIMLINE (BOOSTER WAS ON TOP OF WARHEAD.)

** FRAGMENTS PAIRED TOGETHER

TEST QN0328A0

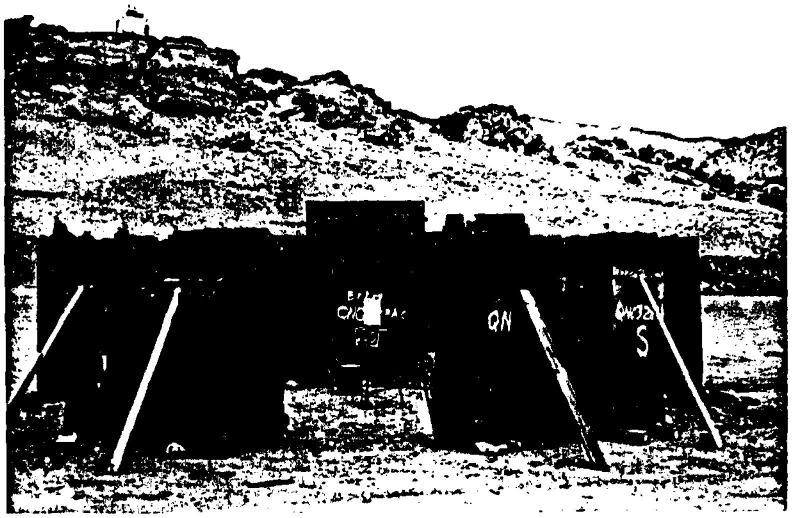
VERTICAL MEASUREMENTS* OF FRAGMENT HIT LOCATIONS (INCHES) ON THE WITNESS SHEETS

| FRAGMENT NUMBER | 30' RADIUS WITNESS SHEET COLUMN 1 | COLUMN*** 2 | COLUMN 3 |
|---|---|---|---|
| 1 | -39 | +68 | +61-1/2 |
| 2 | -47 | +55 | +28 |
| 3 | -41-1/2 | +31 | -4-1/2 |
| 4 | -62-1/2 | +9-1/2 | -4 |
| 5 | -64-1/2 | +2 | -6 |
| 6 | | -8 | |
| 7 | | -9-1/2 | |
| 8 | | -12-1/2 | |
| 9 | | -17-1/2 | |
| 10 | | -22** | |
| 11 | | -26-1/2 | |
| 12 | | -29 | |
| 13 | | -30-1/2 | |
| 14 | | -34-1/2 | |
| 15 | | -34 | |
| 16 | | -34-/12 | |
| 17 | | -35-/12 | |
| 18 | | -34-/12 | |
| 19 | | -36 | |
| 20 | | -37-1/2 | |
| 21 | | -41 | |
| 22 | | -44 | |
| 23 | | -43-1/2 | |
| 24 | | -41-1/2 | |
| 25 | | -42-/12 | |
| 26 | | -46-1/2 | |
| 27 | | -68-1/2 | |

* VERTICAL MEASUREMENTS ARE MEASURED FROM THE BOTTOM OF THE WARHEAD AIMLINE (BOOSTER WAS ON TOP OF WARHEAD.)

** FRAGMENTS PAIRED TOGETHER

*** THE NUMBER OF FRAGMENT LISTED IN COLUMN 2 EXCEEDS THE NUMBER OF FRAGMENT ROWS IN THE WARHEAD BECAUSE THE FRAGMENTS WERE SCABBING




TEST ARENA BEFORE DETONATION

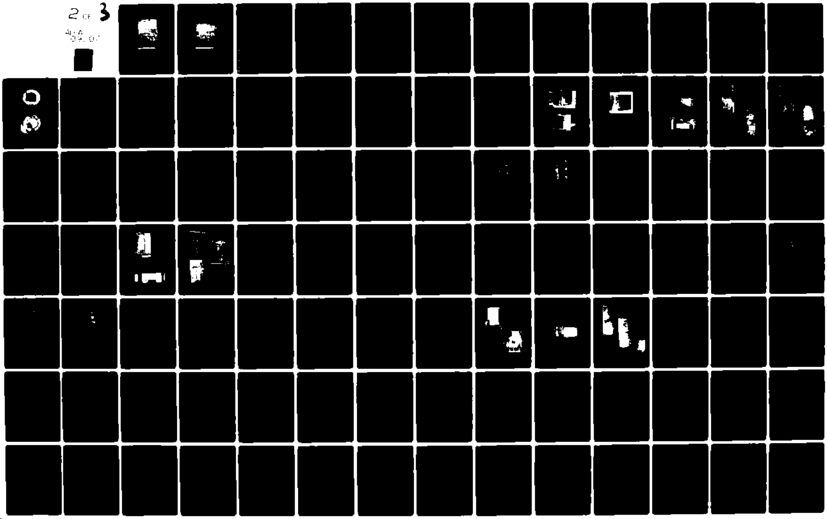
WARHEAD IN POSITION
IN TEST ARENA

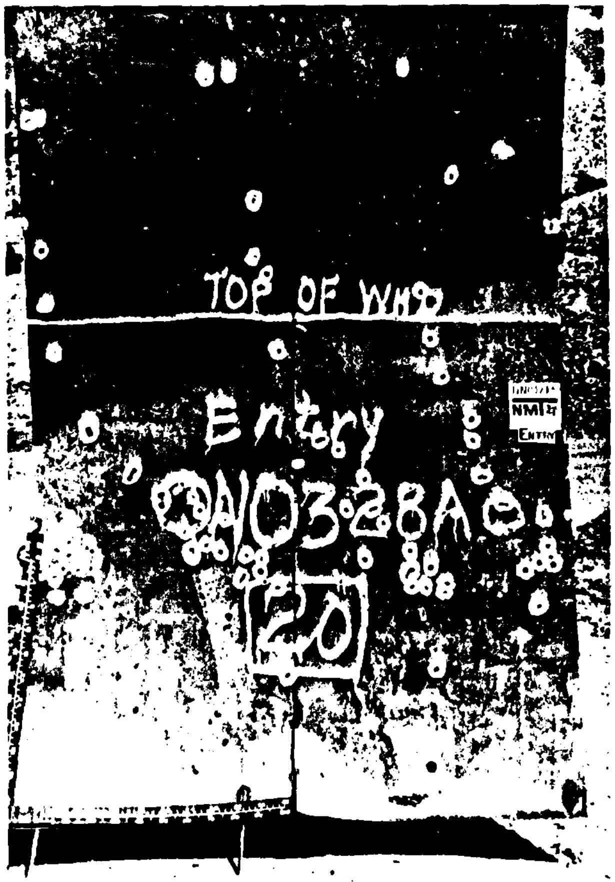


FIGURE 328-11

AD-A092 071 NEW MEXICO INST OF MINING AND TECHNOLOGY SOCORRO TER--ETC F/G 19/1
HIBAL PROGRAM PRELIMINARY WARHEAD-DESIGN. VOLUME I.(U)
SEP 80 N00024-79-C-5333
UNCLASSIFIED NMT/TERA-T-80-1356-U-VOL- NL

2 of 3



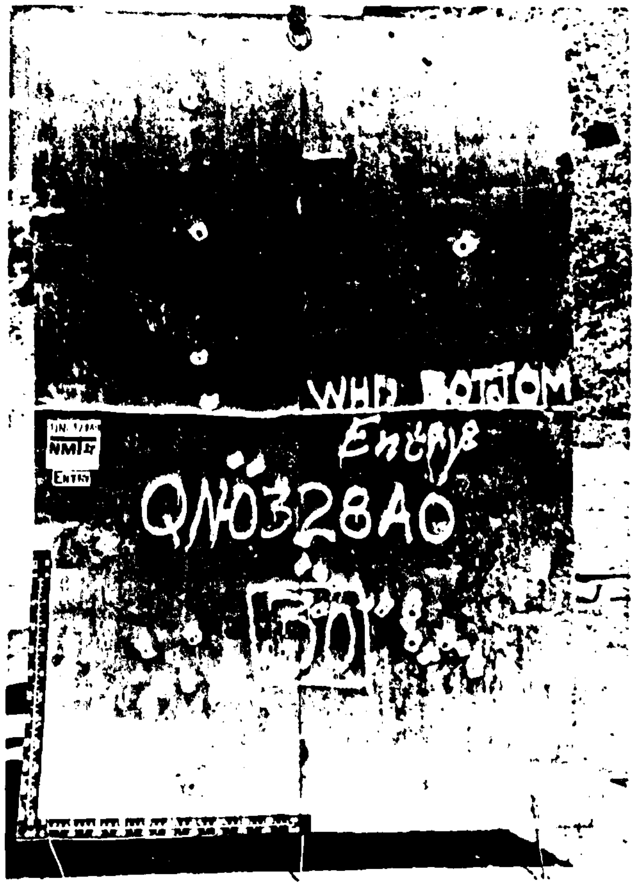



WITNESS SHEET AT 20' RADIUS SHOWING
FRAGMENT HIT LOCATIONS

(5/8-inch SPACING BETWEEN LONGITUDINAL
GROOVES, SYMMETRICALLY TAPERED, H.E.-
FILLED)



FIGURE 328-12




WITNESS SHEET AT 30' RADIUS SHOWING
FRAGMENT HIT LOCATIONS

(5/8" SPACING BETWEEN LONGITUDINAL
GROOVES, SYMMETRICALLY TAPERED IN-
SIDE AND OUT, LAMINAC-FILLED)



FIGURE 328-13

TEST QN0409A0

19" ANNULAR, 200-LB FIREFORMED FRAGMENT/PREFORMED FRAGMENT COMBINATION WARHEAD

## 2.1.6 TEST 5, QN0409A0

### 2.1.6.1 DESIGN SUMMARY AND RATIONALE

This warhead was partly fireformed fragments and partly preformed fragments. The basic design characteristics of the warhead (Figures 409-1 thru 409-3) were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 19-inch |
| INSIDE DIAMETER: | 10.5-inch |
| LENGTH: | 12-1/2-inch |
| CASE THICKNESS: | 0.5-inch |
| CASE MATERIAL: | SAE 4130, (RC-42) |
| WARHEAD WEIGHT: | 200-lb |
| SHROUD: | 0.080-inch titanium for preformed fragment side, 0.020-inch titanium for fireformed fragment side, plus 1-inch urethane foam insulation between warhead and inner shroud |

Three sizes of hex-HIBAL fragments were tested, 500-grain (7/8-inch across flats x 0.47-inch thick), 700-grain (1-inch across flats x 0.47-inch thick) and 900-grain (1-1/8-inch across flats x 0.47-inch thick). The fragments were layed up inside a 0.030-inch skin (mild steel) and potted in laminac.

The fireformed fragment case was grooved circumferentially to provide 14 rows of equal length fragments, each 0.886-inch long. Three choices of spacing between the longitudinal grooves were evaluated, 0.633-inch, 0.886-inch and 1.139-inch. The theoretical fragment weights for these spacings (with no loss in fireforming) were 550-, 770-, and 990-grains.

The decision was made to investigate the possibility that the metal remaining between opposed grooves was the critical design factor, as opposed to the groove depth or ratio of groove depth to case thickness. The most successful warhead design of the first three tests was the first test (QN0225A0), the design for QN0409A0 was therefore based on it.

A. Longitudinal Grooves

The best fragment longitudinal breakout in test QN0225A0 occurred for metal-thickness-remaining values of 0.198 to 0.238-inch. For test QN0409A0, the metal-thickness remaining between longitudinal opposed grooves was varied from 0.190 to 0.260-inch.

The depth of all inside longitudinal grooves was also made 0.110-inch, so as to equal the depth of the circumferential grooves (See discussion below.)

## B. Circumferential Grooves

The results of QN0225A0 indicated that no doubles occurred for metal thickness values remaining of 0.160-inch or less for the non-booster-end fragments. For QN0409A0, the metal remaining values were varied from 0.140-inch to 0.248-inch.

The inside circumferential grooves were uniformly 0.110-inch deep to prevent the inside non-booster-end corner from breaking off. The outside circumferential-groove depths were each varied from 0.142-inch deep to 0.250-inch deep. By using this design, the data should provide a guide to the required groove depths (as a function of groove distance from the booster end) to prevent the fragment doubles.

The circumferential and longitudinal groove designs are summarized in the table below:

| LONGITUDINAL GROOVES | | | CIRCUMFERENTIAL GROOVES | | |
|---|---|---|---|---|---|
| INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING (inch) | INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING (inch) |
| 0.110 | 0.130 | 0.260 | 0.110 | 0.142 | 0.248 |
| 0.110 | 0.140 | 0.250 | 0.110 | 0.155 | 0.235 |
| 0.110 | 0.150 | 0.240 | 0.110 | 0.171 | 0.219 |
| 0.110 | 0.160 | 0.230 | 0.110 | 0.188 | 0.202 |
| 0.110 | 0.170 | 0.220 | 0.110 | 0.207 | 0.183 |
| 0.110 | 0.180 | 0.210 | 0.110 | 0.221 | 0.169 |
| 0.110 | 0.190 | 0.200 | 0.110 | 0.242 | 0.148 |
| 0.110 | 0.200 | 0.190 | 0.110 | 0.250 | 0.140 |

The preformed fragments were fired through a 0.080-inch titanium shroud and the fireformed fragments were fired through a 0.020-inch titanium shroud.

2.1.6.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENA

The objectives of the test were to measure fragment pattern and velocity for both the fireformed and preformed fragments, and to recover a large sample of the fireformed fragments. The test arena is presented in Figure 409-8, with photographs appearing in Figures 409-14 through 409-16.

2.1.6.3 DESCRIPTION OF TEST RESULTS

A. Fragment Quality

Since all inside grooves were 0.110-inch deep, the results are segregated below by outside longitudinal-groove depths.

1. Outside Depth = 0.130-inch (Remaining Metal = 0.260-inch)

No recovery was made of fragments.

2. Outside Depth = 0.140-inch (Remaining Metal = 0.250-inch)

Ten fragments were recovered which were 0.886" wide, all of which were very good quality. The minor fault of the fragments was that some "borrowing" was evident on all fragments, both circumferentially and longitudinally.

Twelve fragments were recovered which were 0.633-inch wide. Five of these fragments (from rows 9 through 13) were joined together in a string. Three of the remaining seven fragments were scabbed. The longitudinal-groove breakout was excellent for all but the scabbed fragments. The circumferential-groove depth for this fragment string was 0.155-inch outside, thus leaving 0.235-inch remaining metal.

3. Outside Depth = 0.150-inch (Remaining Metal = 0.240-inch)

Six fragments were recovered, two of which scabbed. Borrowing was evident to a slight degree on both the longitudinal and circumferential grooves.

4. Outside Depth = 0.160-inch (Remaining Metal = 0.230-inch)

Nine fragments 0.886-inch wide were recovered, two of which were in a doublet. The doublet was in rows 12 and 13; the circumferential groove depth being 0.188-inch at this point (0.202-inch remaining metal). Borrowing was evident to a slight degree on all the fragments. One fragment was a partial.

Eight fragments 0.633-inch wide were recovered, including two doublets, rows 10, 11 and rows 12, 13. Slight borrowing was evident on the longitudinal grooves of the doublets. All other fragments scabbed.

5. <u>Outside Depth = 0.170-inch</u> (Remaining Metal = 0.220-inch)

Three fragments, 1.139" wide, were recovered. Two were in a double (rows 3, 4) and scabbed. The appearance of the scabbed fragment was different than scabbed fragments previously recovered in that the scabbed face was very smooth. The third fragment, from row 2, had borrowing on all four sides.

Eight fragments were recovered which were 0.886-inch wide. Four of the fragments were scabbed (not the "smooth face" scab). remaining four had excellent-quality breakout along the longitudinal grooves, but showed evidence of borrowing along the circumferential grooves.

6. <u>Outside Depth = 0.180-inch</u> (Remaining Metal = 0.210-inch)

Nearly complete success was achieved, in that the fragments averaged 911-grains weight, or about 90% of theoretical.

Eleven fragments (1.139-inch spacing) were recovered (no doublets). Slight borrowing was evident on the longitudinal grooves for all the fragments. There was one partial fragment. Borrowing was evident circumferentially on two of the fragments, row 3 and 13. The outside circumferential-groove depth was 0.221-inch, or 0.169-inch remaining metal.

7. <u>Outside Depth = 0.190-inch</u> (Remaining Metal = 0.200-inch)

Nearly complete success was achieved, in that most, fragments were excellent quality, averaging 732-grains each, or about 95% of theoretical.

Twenty two fragments were recovered (0.886-inch wide), including one double (rows 4, 5) and one scabbed fragment (row 10).

The 0.020-inch titanium shroud left an imprint on the fragments, which had not occurred in any of the previous tests. No other damage than the imprint can be attributed to the shroud.

Recovered fragment weights are presented on page 409-24.

## B. Fragment Pattern and Velocity

The fragment polar-angle and velocity characterizations, for both the preformed and fireformed fragments, are presented in Figures 409-5 through 409-7. The data for the fireformed fragments are not as complete as the data for the preformed fragments because the column of fragments which was intended for velocity and polar-angle characterization did not properly breakup, circumferentially (i.e., fragment multiples occurred). The data are presented in Figure 409-8 and 409-9.

## C. CONCLUSIONS

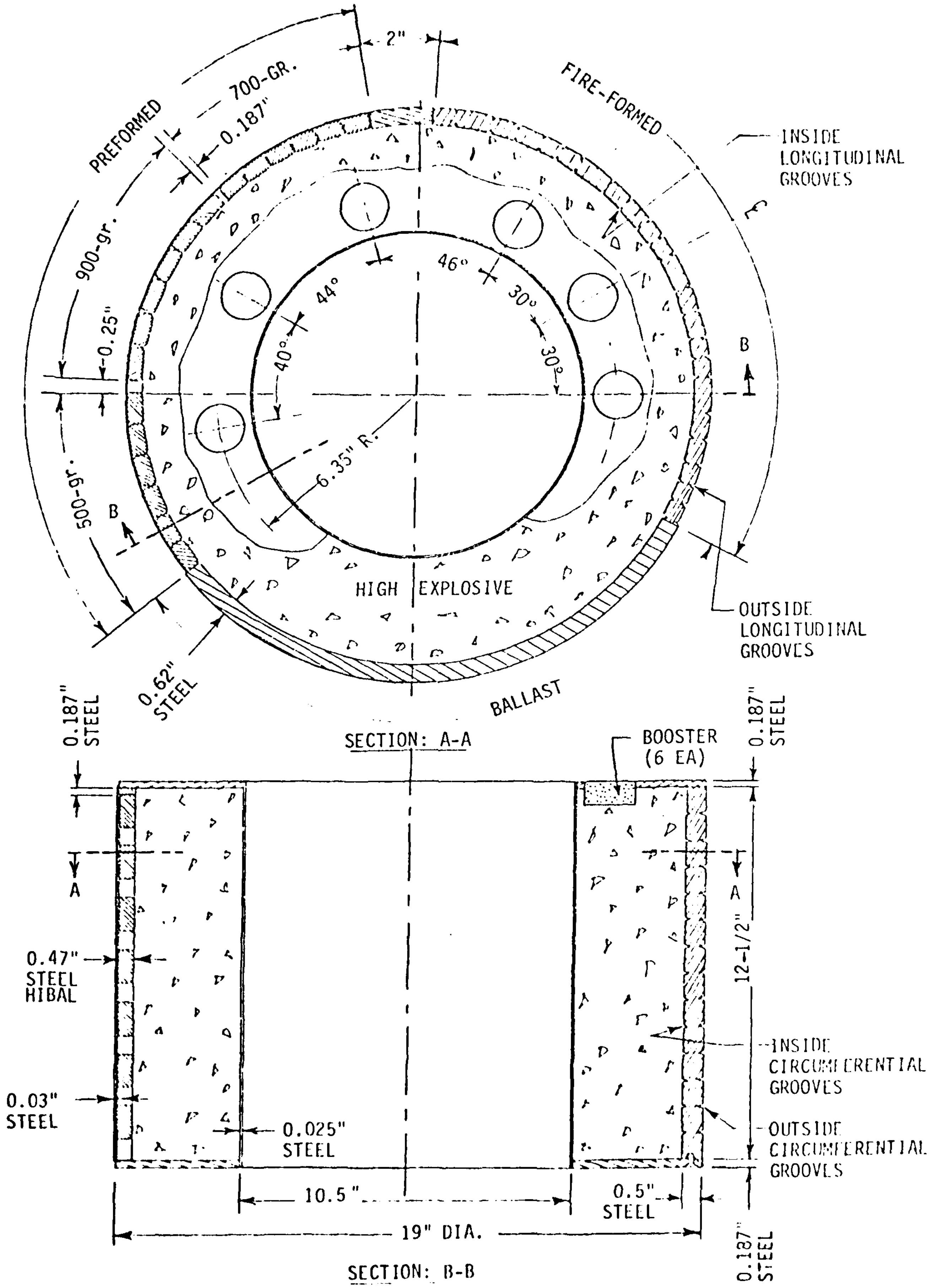
### 1. Fireformed Fragment Warhead

a. Longitudinal opposed grooves which provide for 0.250-inch or less metal remaining between the apexes of grooves will provide for proper case breakout along the longitudinal grooves.

b. For fragments near the booster end of the warhead, circumferential grooves should provide for about 0.240-inch remaining metal between the apexes of the grooves. For fragments near the non-booster end of the warhead, the circumferential grooves should provide for about 0.200-inch remaining metal.

### 2. Preformed Fragment Warhead

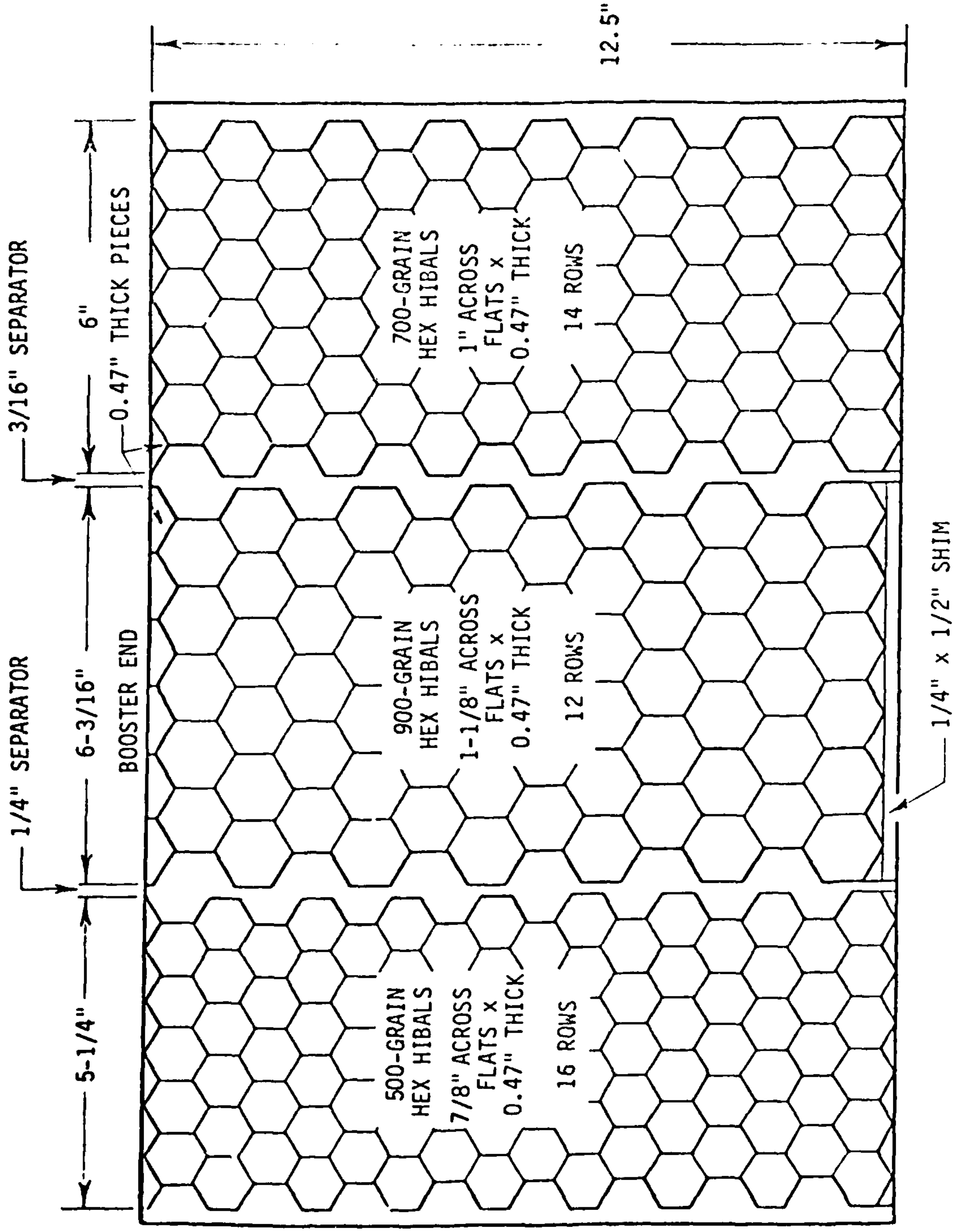
There is no need for further 19-inch diameter, 200-lb preformed fragment warhead tests. The fragments were satisfactory in quality, as judged from the witness sheet pattern, and the pattern and velocity date were adequate to formulate warhead characterization models for the second phase end game analysis.




19" O.D. ANNULAR WARHEAD



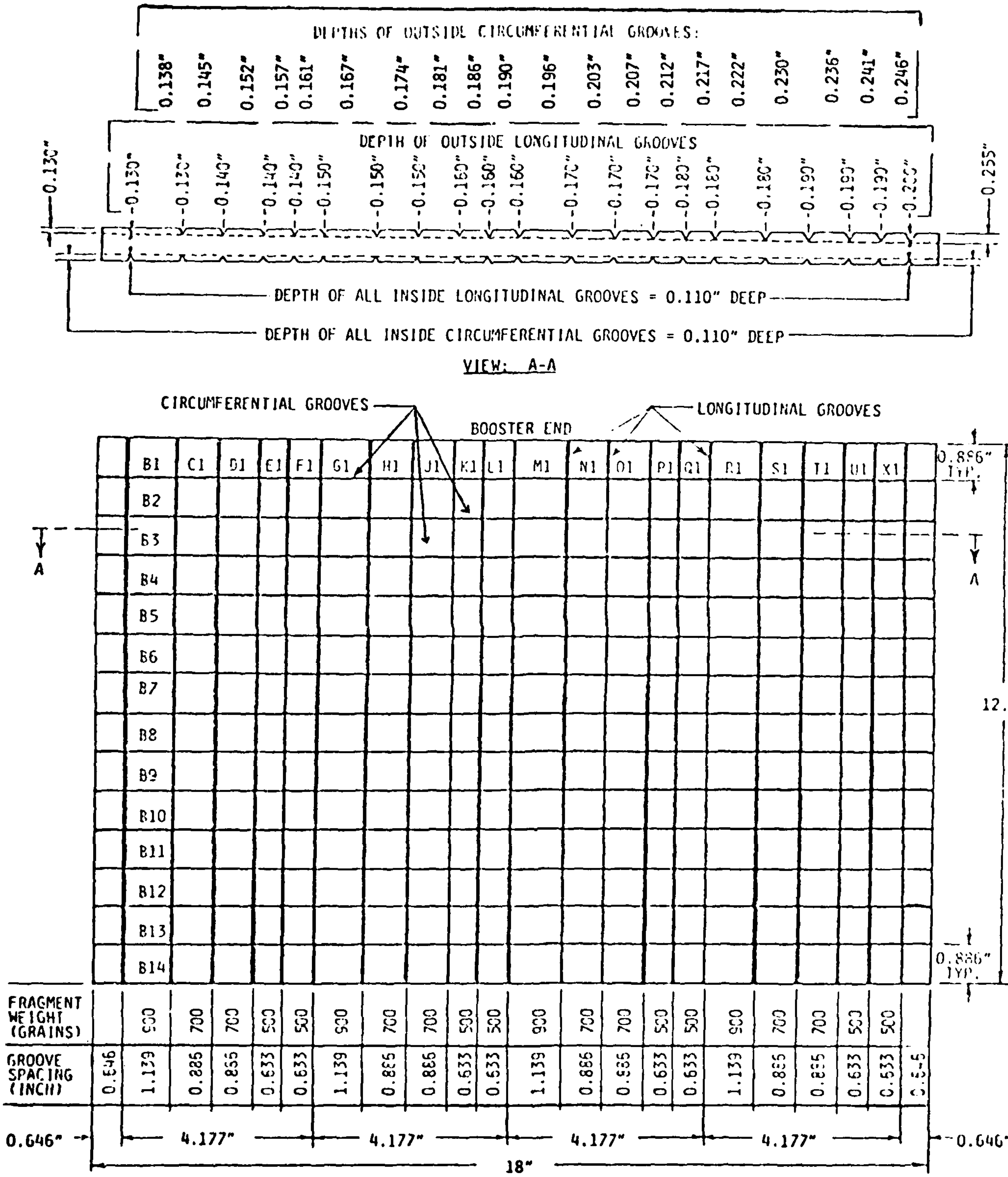
FIGURE 409-1




HEX HIBAL DETAILS
TEST QN0409A



FIGURE 409-2




INSIDE VIEW

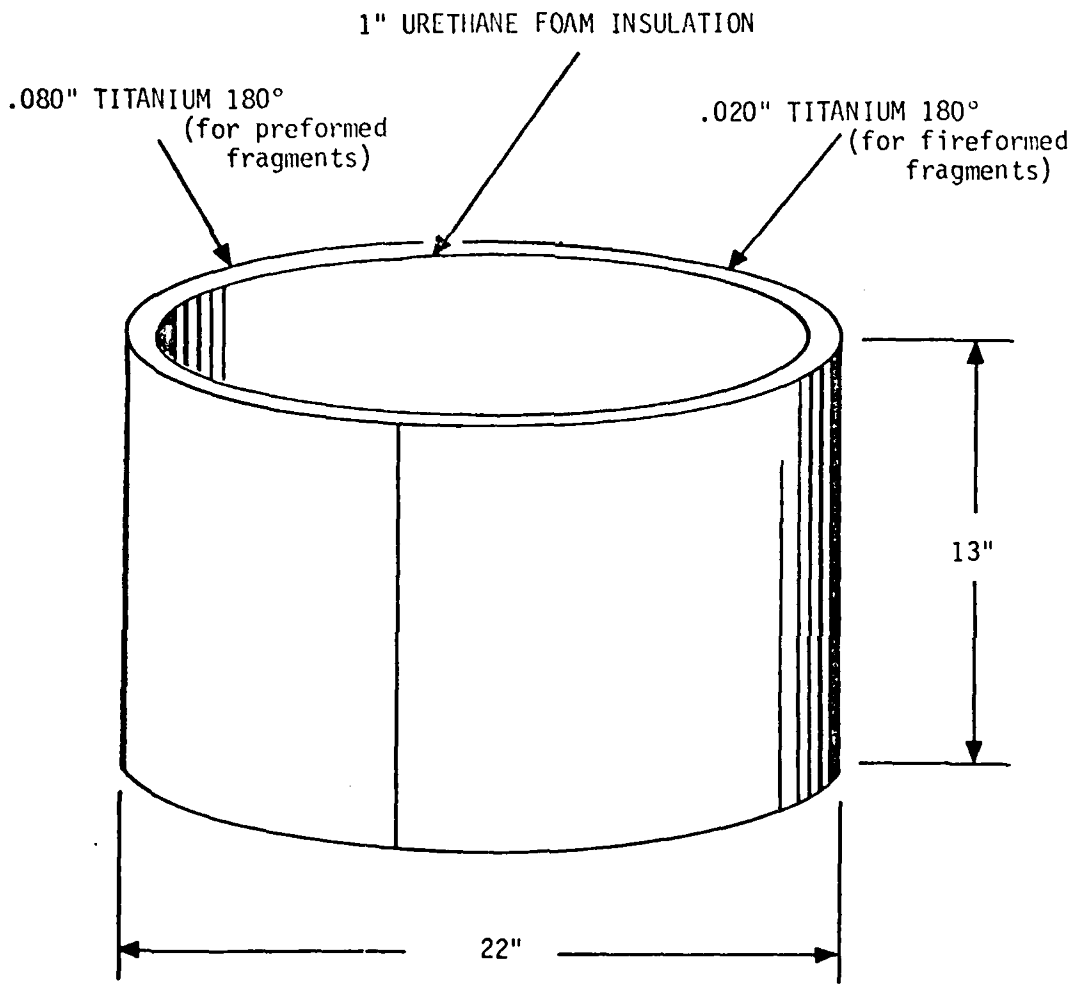
GROOVE DETAIL FOR FIRE-FORMED FRAGMENTS

19 " O.D. ANNULAR WARHEAD

TEST: QN0409A0



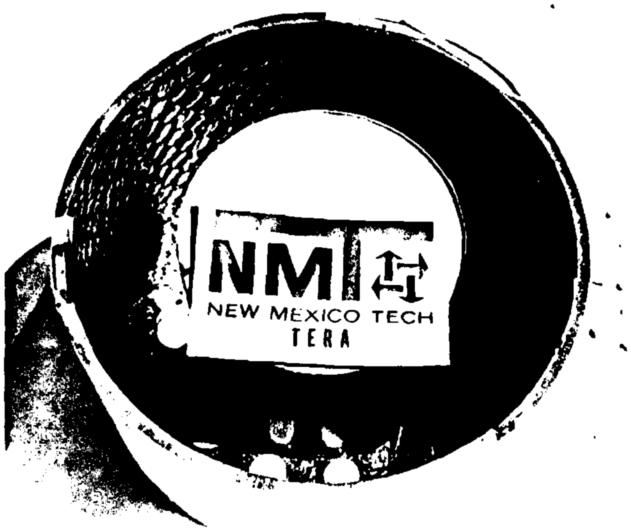
FIGURE 409-3




SHROUD USED IN TEST QN0409A0
FOR THE 19" O.D. ANNULAR WARHEAD



FIGURE 409-4




WARHEAD BEFORE BEING LOADED WITH EXPLOSIVE

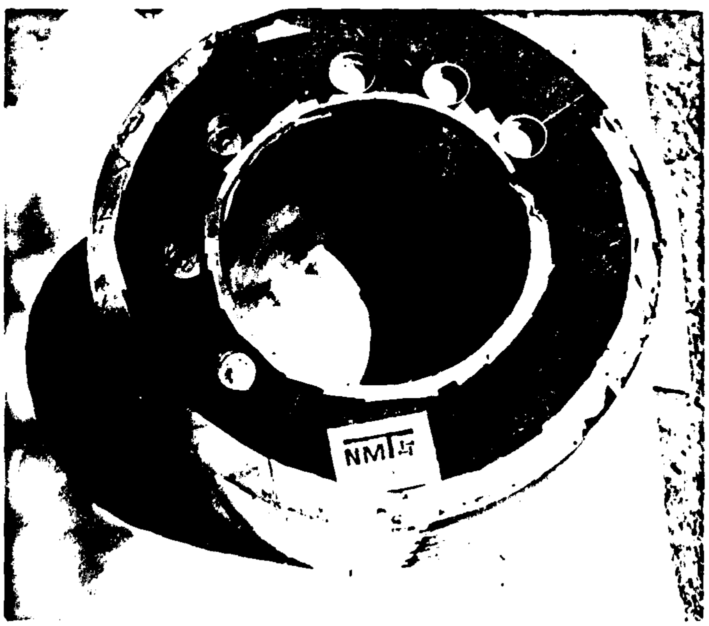
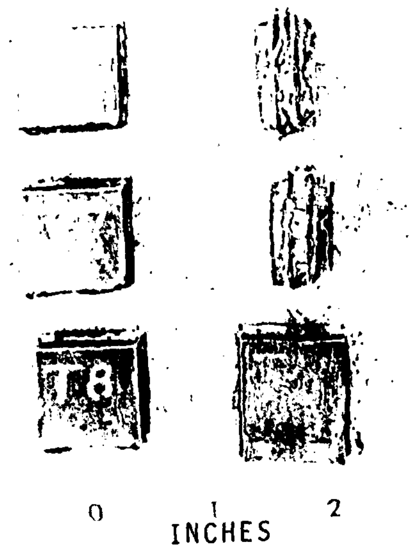
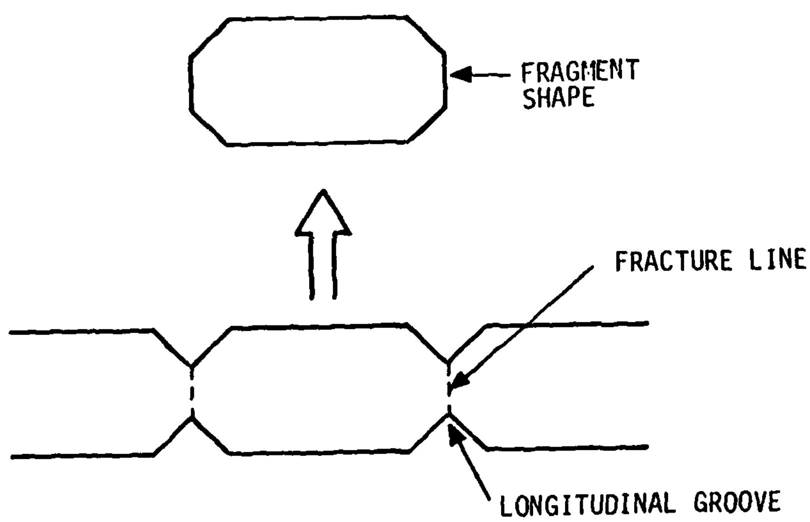




FIGURE-409-5




QN0409A0



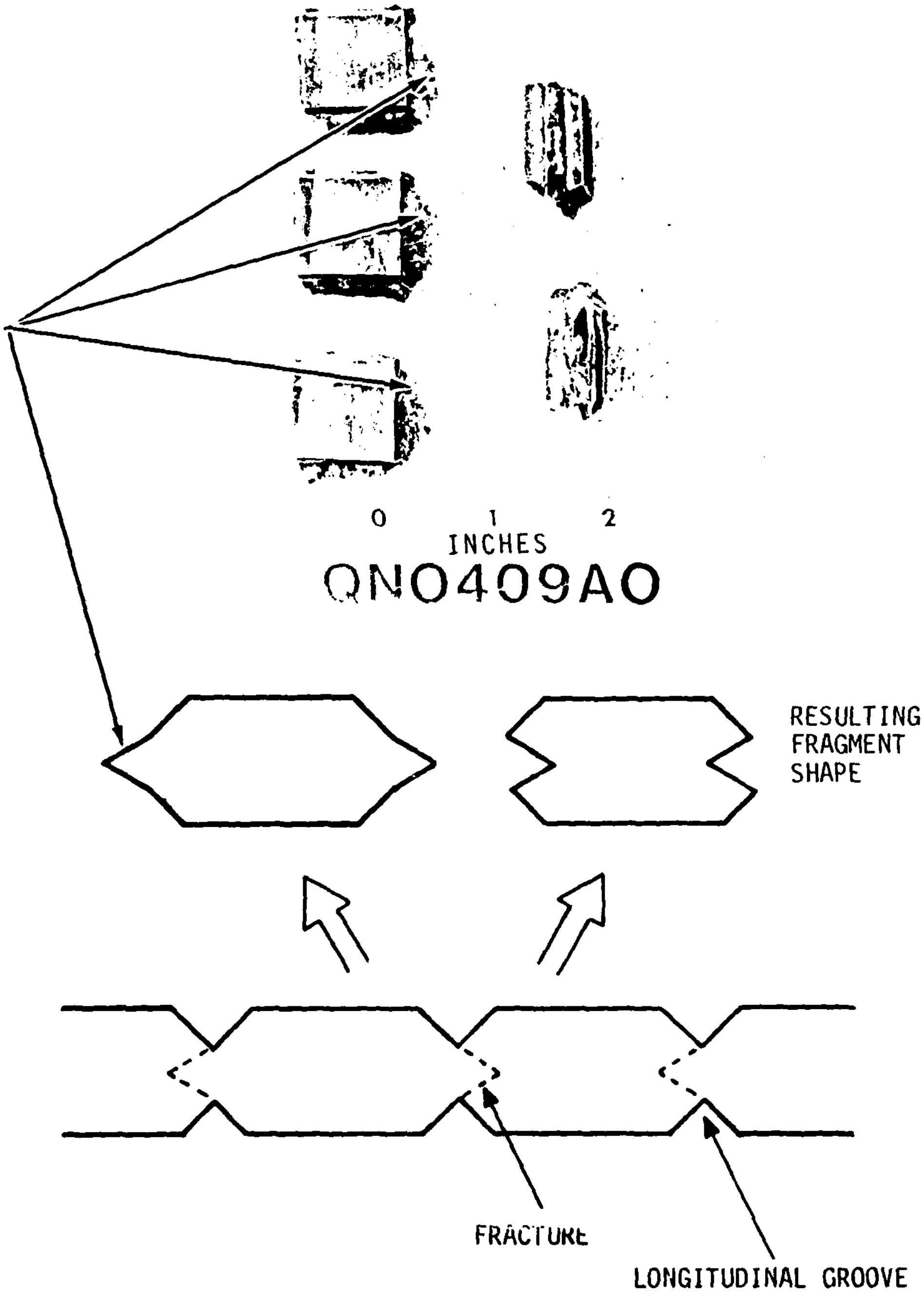

H.E. SIDE

FRAGMENT SHAPE RESULTING WHEN THE METAL REMAINING BETWEEN LONGITUDINAL INSIDE AND OUTSIDE GROOVES IS BETWEEN 0.200" AND 0.240"

EXAMPLE FRAGMENTS FROM TEST QN0409A0



FIGURE-409-6

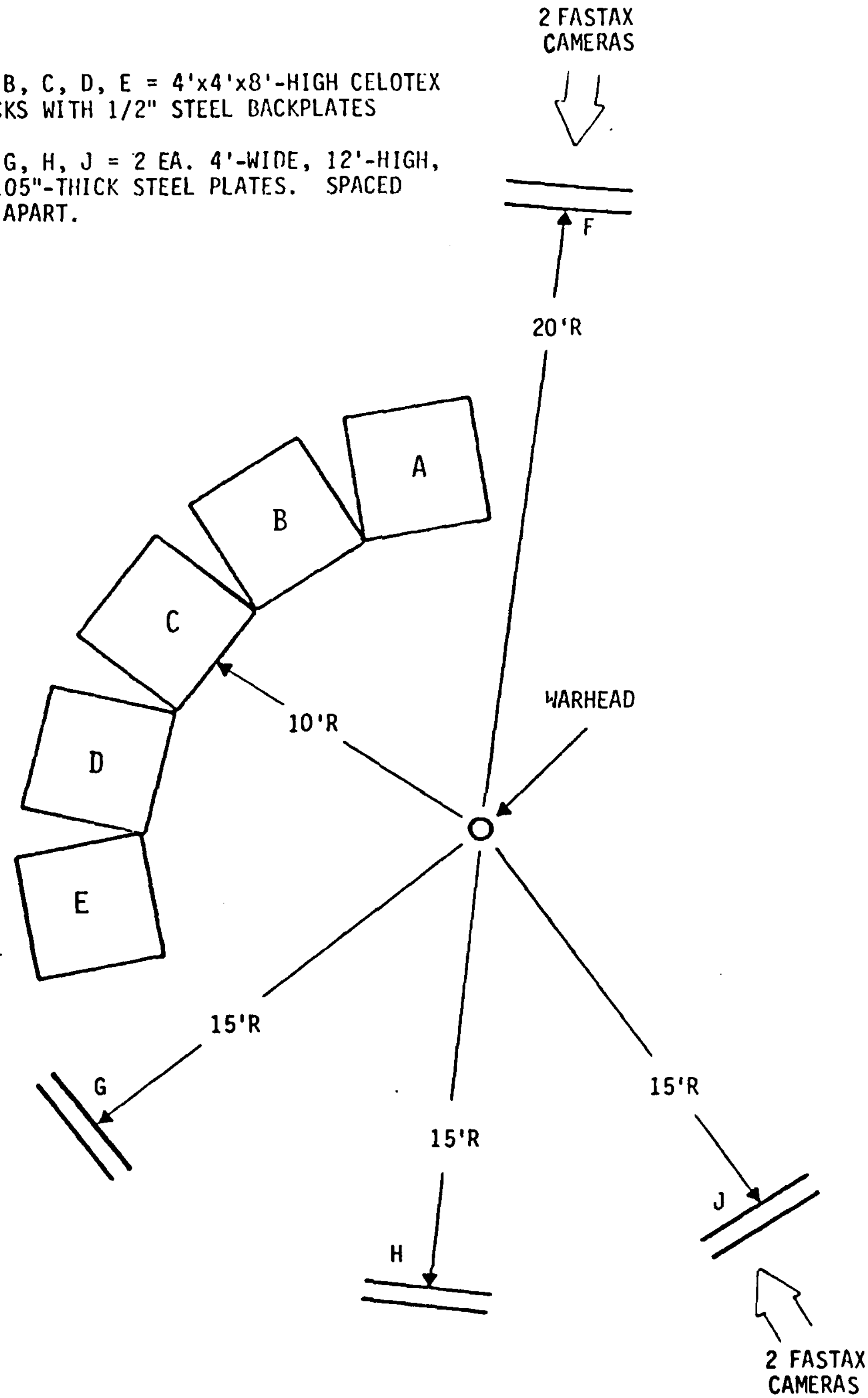



REDUCED-WEIGHT FRAGMENTS RESULTING WHEN THE METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.240" THROUGH 0.260"

EXAMPLE FRAGMENTS FROM TEST QN0409A0

TARGETS: A, B, C, D, E = 4'x4'x8'-HIGH CELOTEX PACKS WITH 1/2" STEEL BACKPLATES

TARGETS: F, G, H, J = 2 EA. 4'-WIDE, 12'-HIGH, 0.105"-THICK STEEL PLATES. SPACED 6" APART.




ARENA FOR TEST QN0409A0



FIGURE-409-8

TEST QN0409A0

SUMMARY OF FRAGMENT POLAR EJECTION ANGLE AND VELOCITY RESULTS FOR HEX HIBAL FRAGMENTS THROUGH .080" TITANIUM SHROUD

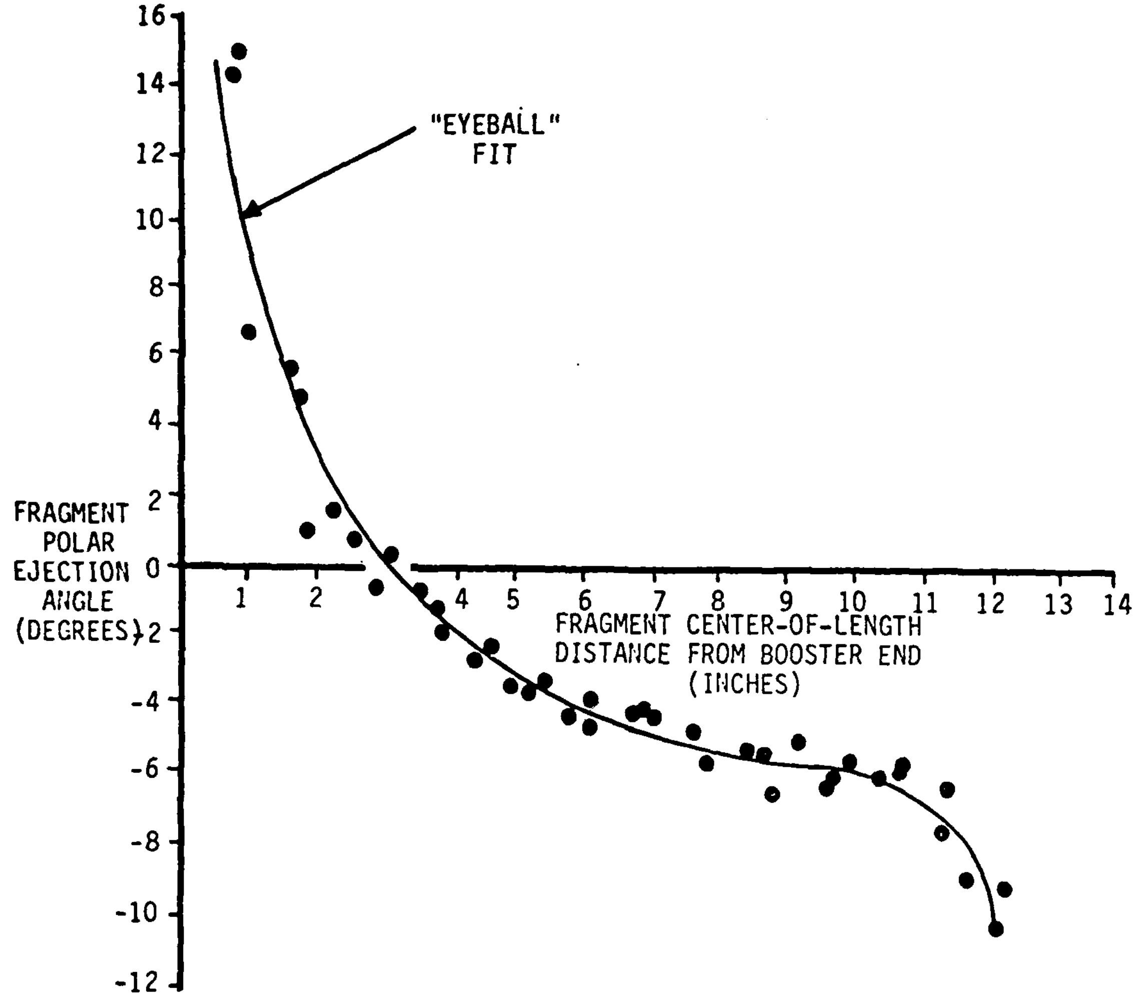
| FRAGMENT ROW[1] | FRAGMENT C.G. DISTANCE FROM BOOSTER END (INCHES) | FRAGMENT HIT LOCATIONS RELATIVE TO BOOSTER-END | | | POLAR ANGLE | AVERAGE VELOCITY(0-15') |
|---|---|---|---|---|---|---|
| | | 500-gr | 700-gr | 900-gr | | |
| 1(5) | 0.8 | +45.5 | | | +14.4° | 3400 |
| 1(7) | 0.9 | | +47.3 | | +15.0° | |
| 1(9) | 1.0 | | | +20.5 | +6.8° | |
| 2(5) | 1.6 | +16.5 | | | +5.7° | 3800 |
| 2(7) | 1.8 | | +13.5 | | +4.9° | |
| 2(9) | 1.9 | | | +1.3 | +1.0° | |
| 3(5) | 2.3 | +3.3 | | | +1.8° | 4200 |
| 3(7) | 2.6 | | 0 | | +0.8° | |
| 3(9) | 2.9 | | | -4.8 | -0.6° | |
| 4(5) | 3.1 | -2.5 | | | +0.2° | 4400 |
| 4(7) | 3.5 | | -5.8 | | -0.7° | |
| 5(5) | 3.8 | -8.0 | | | -1.3° | 4600 |
| 4(9) | 3.9 | | | -10.0 | -1.9° | |
| 5(7) | 4.4 | | -12.7 | | -2.6° | |
| 6(5) | 4.6 | -12.3 | | | -2.4° | 4600 |
| 5(9) | 4.9 | | | -16.0 | -3.5° | |
| 6(7) | 5.2 | | -16.3 | | -3.5° | |
| 7(5) | 5.4 | -16.0 | | | -3.4° | 4800 |
| 6(9) | 5.8 | | | -19.3 | -4.3° | |
| 7(7) | 6.1 | | -20.7 | | -4.6° | |
| 8(5) | 6.1 | -18.5 | | | -3.9° | 4800 |
| 7(9) | 6.8 | | | -20 | -4.2° | |
| 9(5) | 6.9 | -19.8 | | | -4.1° | 4900 |
| 8(7) | 7.0 | | -20.3 | | -4.2° | |
| 10(5) | 7.6 | -22.3 | | | -4.7° | 4900 |
| 8(9) | 7.8 | | | -24.8 | -5.4° | |
| 9(7) | 7.8 | | -25.2 | | -5.5° | |
| 11(5) | 8.4 | -25.0 | | | -5.3° | 4900 |
| 10(7) | 8.7 | | -25.3 | | -5.3° | |
| 9(9) | 8.8 | | | -28.3 | -6.2° | |
| 12(5) | 9.2 | -25.0 | | | -5.0° | 4900 |
| 11(7) | 9.6 | | -28.8 | | -6.1° | |
| 10(9) | 9.7 | | | -28.5 | -6.0° | |
| 13(5) | 9.9 | -27.5 | | | -5.6° | 4900 |
| 12(7) | 10.4 | | -29.2 | | -6.0° | |
| 11(9) | 10.7 | | | -29 | -5.8° | |
| 14(5) | 10.7 | -28.8 | | | -5.7° | 4600 |
| 13(7) | 11.3 | | -35.3 | | -7.6° | |
| 15(5) | 11.4 | -30.8 | | | -6.2° | 4500 |
| 12(9) | 11.7 | | | -37.3 | -8.1° | |
| 14(7) | 12.1 | | -44.8 | | -10.3° | |
| 16(5) | 12.2 | -41.3 | | | -9.2° | 4500 |

[1] NUMBERS IN PARENTHESIS INDICATE FRAGMENT SIZE



FIGURE-409-9

19" O.D., 1/2" CASE




FRAGMENT POLAR EJECTION ANGLE AS A FUNCTION OF THE FRAGMENT CENTER-OF-LENGTH DISTANCE FROM THE BOOSTER END OF THE WARHEAD
TEST QN0409A0



FIGURE-409-10

TEST QN0409A0

FRAGMENT VELOCITY AND POLAR ANGLES FOR FIREFORMED FRAGMENTS THROUGH 0.020" TITANIUM SHROUD

| FRAGMENT ROW* | POLAR EJECTION ANGLE | FRAGMENT AVERAGE VELOCITY (0-20-ft) |
|---|---|---|
| 1 | 5° | 4300 |
| 2 | 2.7° | 4800 |
| 3 | -0.6° | 5260 |
| 4 | -0.9° | 5260 |
| 5,6 | -3.0° | 5400 |
| 7 | -4.6° | 5500 |
| 8,9,10 | -5.3° | 5500 |
| 11,12 | -5.5° | 5500 |
| 13 | ----- | ---- |
| 14 | ----- | ---- |

*THE FRAGMENT ROWS LISTED IN THE SAME LINE WERE JUDGED TO BE PAIRED TOGETHER BASED ON THE HOLE SIZES IN THE WITNESS SHEETS.

TEST QN0409A0

VERTICAL MEASUREMENTS* OF FRAGMENT HIT LOCATIONS (INCHES) ON THE WITNESS SHEETS

| FRAGMENT ROW | 900-GRAIN HEX HIBAL, 15' RADIUS | | | | AVERAGE |
|---|---|---|---|---|---|
| | COLUMN 1 | COLUMN 2 | COLUMN 3 | COLUMN 4 | |
| 1 | | -22 | | -19 | +20.5 |
| 2 | +0.5 | | -2 | | +1.3 |
| 3 | | -5 | | -4.5 | -4.8 |
| 4 | -10.5 | | -9.5 | | -10.0 |
| 5 | | -15.5 | | -16.5 | -16.0 |
| 6 | -20 | | -18.5 | | -19.3 |
| 7 | | -19 | | -21 | -20 |
| 8 | -25.5 | | -24 | | -24.8 |
| 9 | | -28 | | -28.5 | -28.3 |
| 10 | -30 | | -27 | | -28.5 |
| 11 | | -29 | | -29 | -29 |
| 12 | -38 | | -36.5 | | -37.3 |

| FRAGMENT ROW | FIRE-FORMED HIBALS -20' RADIUS COLUMN 1 | |
|---|---|---|
| 1 | +20.5 | |
| 2 | +10.0 | |
| 3 | -5.0 | |
| 4 | -7.0 | |
| 5 | -17.0 | FRAGMENT DOUBLE |
| 6 | -17.0 | |
| 7 | -26.5 | |
| 8 | -30 | |
| 9 | -30 | FRAGMENT TRIPLE |
| 10 | -30 | |
| 11 | -33 | FRAGMENT DOUBLE |
| 12 | -33 | |
| 13 | --- | (HIT BELOW WITNESS SHEET) |
| 14 | --- | |

* VERTICAL MEASUREMENTS ARE FROM THE TOP OF THE WARHEAD AIMLINE.

TEST QN0409A0

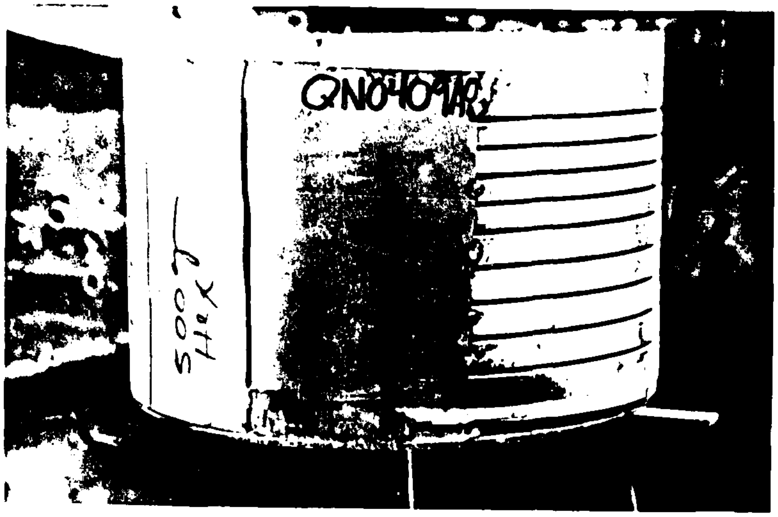
VERTICAL MEASUREMENT* OF FRAGMENT HIT LOCATIONS (INCHES) ON THE WITNESS SHEETS

| FRAGMENT ROW | 500-GRAIN HEX HIBAL COLUMN 1 | COLUMN 2 | COLUMN 3 | COLUMN 4 | AVERAGE |
|---|---|---|---|---|---|
| 1 | | +45 | | +46 | +45.5 |
| 2 | +18 | | +15 | | +16.5 |
| 3 | | +2.5 | | +4 | +3.3 |
| 4 | -2 | | -3 | | -2.5 |
| 5 | | -9 | | -7 | -8 |
| 6 | -12 | | -12.5 | | -12.3 |
| 7 | | -16.5 | | -15.5 | -16.0 |
| 8 | -18.5 | | -18.5 | | -18.5 |
| 9 | | -21 | | -18.5 | -19.8 |
| 10 | -22.5 | | -22 | | -22.3 |
| 11 | | -25.5 | | -24.5 | -25.0 |
| 12 | | | -25 | | -25.0 |
| 13 | | -28 | | -27 | -27.5 |
| 14 | -29.5 | | -28 | | -28.8 |
| 15 | | -31.5 | | -30 | -30.8 |
| 16 | -43.5 | | -39 | | -41.3 |

| FRAGMENT ROW | 700-GRAIN HEX HIBAL COLUMN 1 | COLUMN 2 | COLUMN 3 | COLUMN 4 | COLUMN 5 | COLUMN 6 | AVERAGE |
|---|---|---|---|---|---|---|---|
| 1 | +45.5 | | +47.5 | | +49 | | +47.3 |
| 2 | | +13 | | +14 | | --- | +13.5 |
| 3 | -0.5 | | 0 | | +0.5 | | 0 |
| 4 | | -6 | | -6.5 | | -5 | -5.8 |
| 5 | -12 | | -13 | | -13 | | -12.7 |
| 6 | | -15.5 | | -17.5 | | -16 | -16.3 |
| 7 | -20.5 | | -22 | | -19.5 | | -20.7 |
| 8 | | -15.5 | | -23 | | -22.5 | -20.3 |
| 9 | -25 | | -25.5 | | -25 | | -25.2 |
| 10 | | -22.5 | | -27 | | -26.5 | -25.3 |
| 11 | -29 | | -28 | | -29.5 | | -28.8 |
| 12 | | -26 | | -30 | | -31.5 | -29.2 |
| 13 | -35 | | -34 | | -37 | | -35.3 |
| 14 | | --- | | -42.5 | | -47 | -44.8 |

* VERTICAL MEASUREMENTS ARE FROM TOP OF WARHEAD AIMLINE

TEST: QN0409A0



WARHEAD AT TEST SITE WITH SHROUD REMOVED

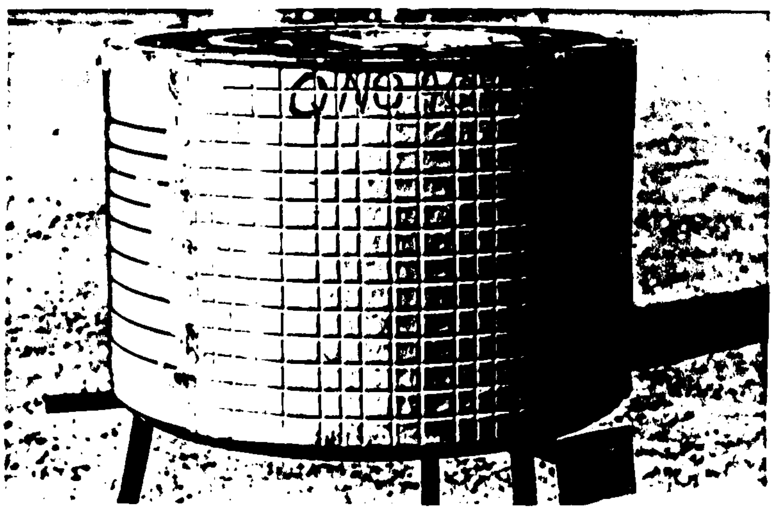
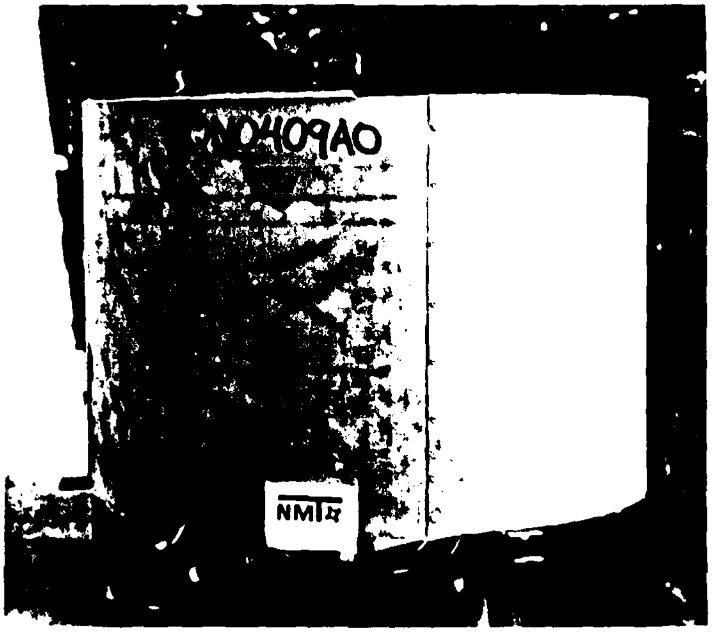


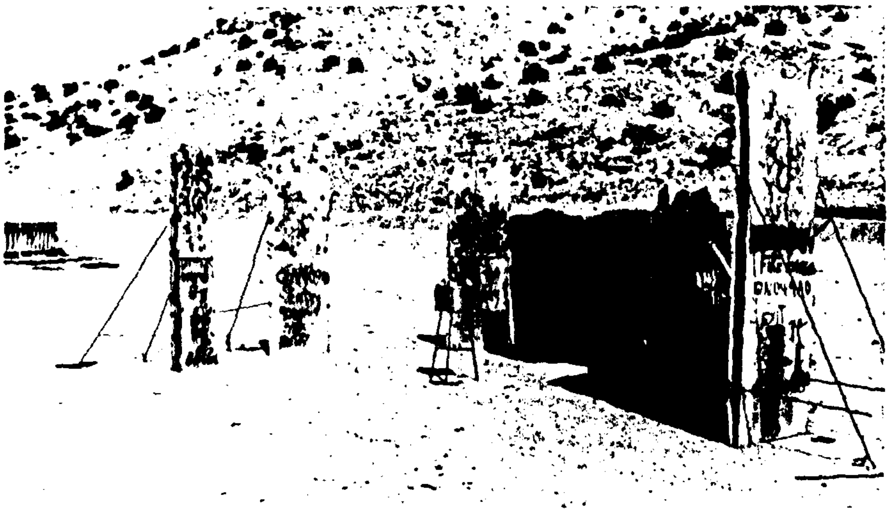


FIGURE-409-14

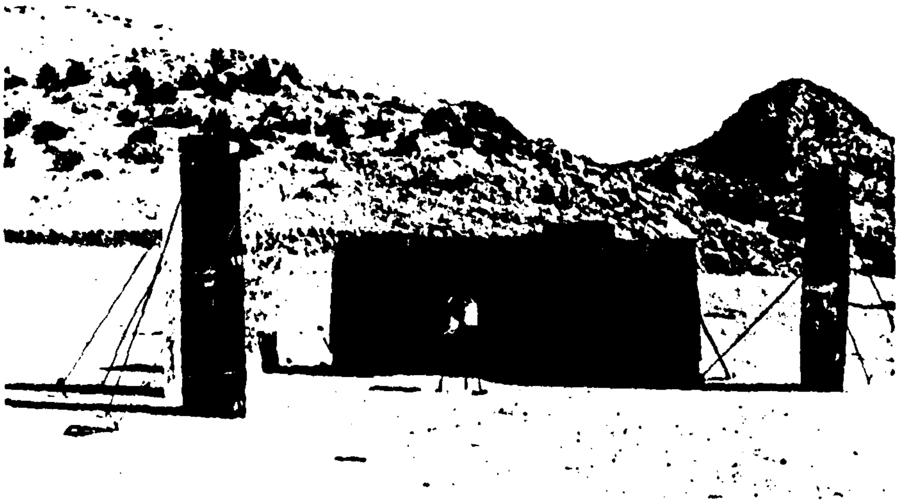
TEST QN0409A0



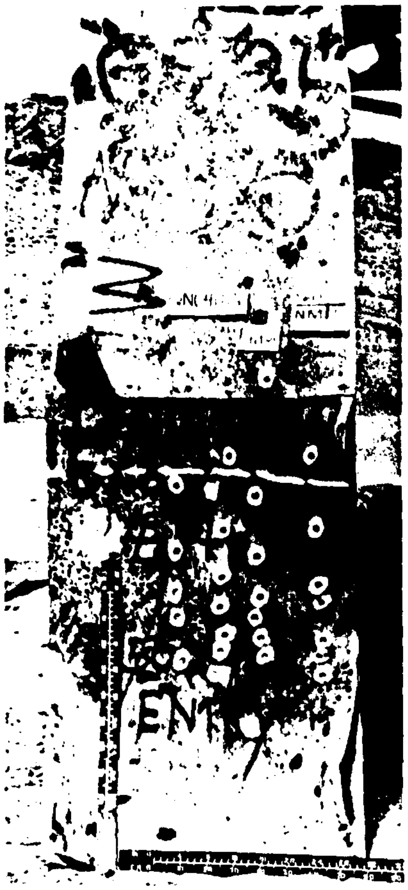

WARHEAD AT TEST SITE WITH SHROUD INSTALLED



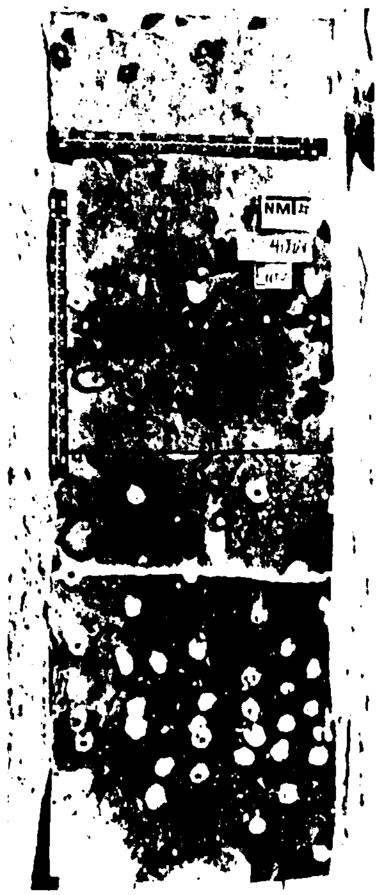
TEST ARENA BEFORE DETONATION



TEST: QN0409A0



500-gr FRAGMENT WITNESS SHEET AFTER TEST; 15' RADIUS

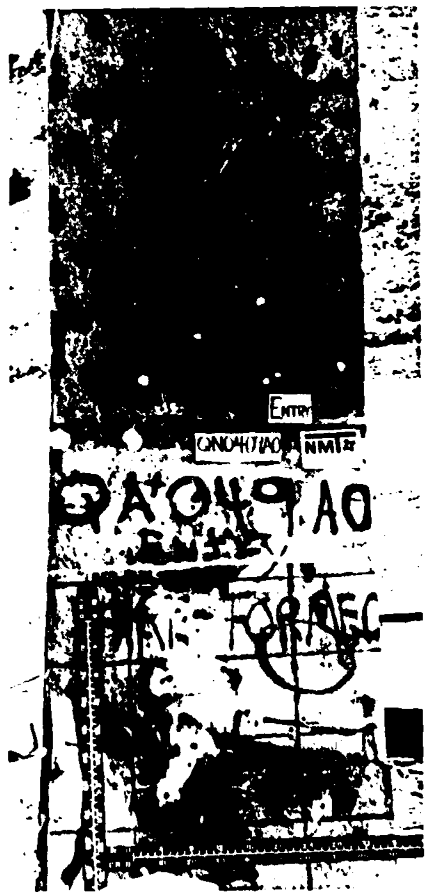


700-gr FRAGMENT WITNESS SHEET AFTER TEST; 15' RADIUS



FIGURE-409-17

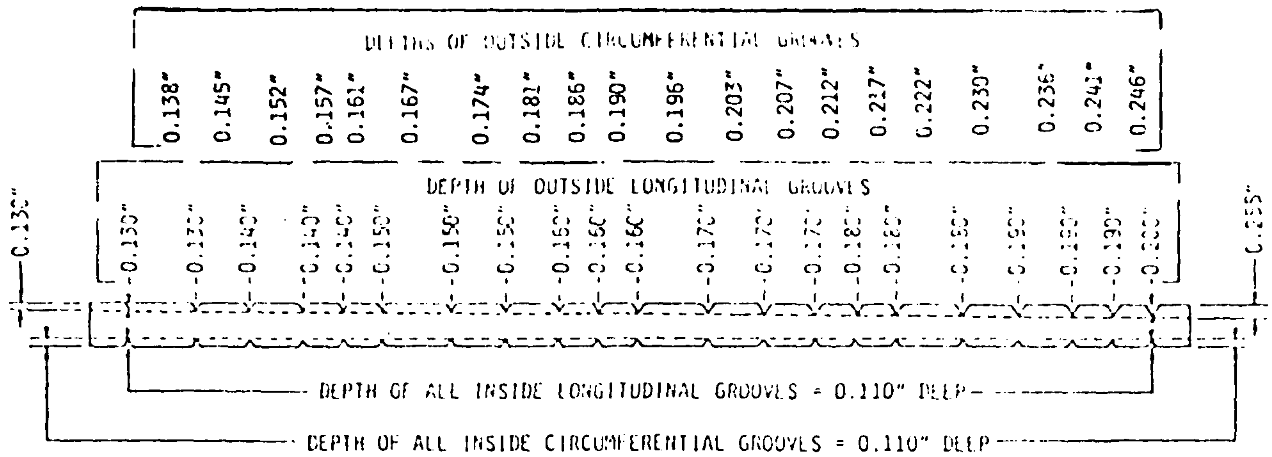
900-GRAIN FRAGMENT WITNESS
SHEET AFTER TEST; 15' RADIUS




FIRE-FORMED HIBAL WITNESS
SHEET AFTER TEST; 20' RADIUS



FIGURE-409-18




VIEW: A-A

CIRCUMFERENTIAL GROOVES — LONGITUDINAL GROOVES

BOOSTER END

| ROW NUMBER / COLUMN NUMBER | B1 | C1 | D1 | E1 | F1 | G1 | H1 | J1 | K1 | L1 | M1 | N1 | O1 | P1 | Q1 | R1 | S1 | T1 | U1 | V1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | B2 | 741 | 790 | 370 | 577 | | 383 | 867 | | | 975 | 782 | 387 | | | | 755 | 733 | | | |
| 3 | B3 | | 799 | | 556 | | 427 | | | | 958 | 745 | 424 | | | 932 | 739 | 730 | | | |
| 4 | B4 | | 773 | | | | 682 | | | | 994 | | 730 | | | 894 | 1469 | 708 | | | |
| 5 | B5 | | 784 | 361 | 1145 | | | 745 | | | | | 332 | | | 932 | | 733 | | | |
| 6 | B6 | | | 560 | | | | 750 | | | | 716 | | | | 904 | 748 | 721 | | | |
| 7 | B7 | | 769 | 244 | 583 | | | 731 | | | | | | | | 909 | | 713 | | | |
| 8 | B8 | | 742 | 565 | 560 | | | 636 | | | | | | 162 | | 894 | 708 | 719 | | | |
| 9 | B9 | | 731 | 2809 | | | 765 | 603 | | | | | | | | 932 | 745 | | | | |
| 10 | B10 | | | | | | | | | | | | | | | 927 | 715 | 213 | | | |
| 11 | B11 | | 704 | | | | | | | | | | | | | 846 | 741 | | | | |
| 12 | B12 | | | | | | | 1525 | | | | | | | | 932 | 722 | | | | |
| 13 | B13 | | 775 | | | | 784 | | | | | | | | | 965 | 744 | | | | |
| 14 | B14 | | 819 | 616 | 622 | | 838 | 830 | | | | | 779 | | | | 792 | 793 | | | |
| FRAGMENT* WEIGHT (GRAINS) | 900 | 700 | 700 | 500 | 500 | 900 | 700 | 700 | 500 | 500 | 900 | 700 | 700 | 500 | 500 | 900 | 700 | 700 | 500 | 500 | |
| GROOVE SPACING (INCH) 0.646 | 1.139 | 0.885 | 0.885 | 0.633 | 0.633 | 1.139 | 0.885 | 0.885 | 0.633 | 0.633 | 1.139 | 0.885 | 0.885 | 0.633 | 0.633 | 1.139 | 0.885 | 0.885 | 0.633 | 0.633 | 0.646 |

0.886" TYP. 12.5" 0.886" TYP.

0.646" — 4.177" — 4.177" — 4.177" — 4.177" — 0.646"

18"

INSIDE VIEW
GROOVE DETAIL FOR FIRE-FORMED FRAGMENTS

## RECOVERED FRAGMENT WEIGHTS (GRAINS)
## TEST: QN0409A0

*Assuming 10% weight loss in fireforming.



FIGURE 409-19

TEST QN0429A0

11.5", 200-LB, PREFORMED-FRAGMENT/FIREFORMED-FRAGMENT COMBINATION-WARHEAD

### 2.1.7 TEST 6, QN0429A0

#### 2.1.7.1 DESIGN SUMMARY AND RATIONALE

This warhead was a combined (preformed plus fireformed) fragment warhead. The basic design characteristics of the warhead (Figure 429-1 and 429 2) were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 11.5-inch |
| INSIDE DIAMETER: | 2.875-inch |
| LENGTH: | 18.375-inch |
| CASE THICKNESS: | 0.563-inch |
| CASE MATERIAL: | |
| Preformed Fragments: | SAE 4130, RC44-47 |
| Fireformed Fragments: | SAE 4140, RC37-42 |
| SKIN THICKNESS: | |
| Preformed Fragments: | 0.015-inch (mild steel) |
| WARHEAD WEIGHT: | 200-lb |
| SHROUD: | Two steel skins, 0.020-inch inside, 0.030-inch outside, plus 1-inch urethane foam insulation between warhead and inner shroud |

The preformed hex-HIBAL fragments were all 0.548-inch thick, and were the following sizes: 3/4-inch across flats (500-grian); 7/8-inch across flats (700-grain); and 1-inch across flats (900-grain). They were packaged with a 0.015-inch steel outside skin and potted in laminac.

The fireformed-fragment case was grooved circumferentially to provide 19 rows of equal-length fragments, 0.888-inch long. The spacing between longitudinal grooves was 0.75-inch. No variation in spacing between longitudinal grooves was made because it was not judged that the spacing between longitudinal grooves would affect the fragment quality. The theoretical weight of the fragments (before any weight loss due to fireforming) was 750-grains.

A. Longitudinal Grooves

0.250-inch metal thickness remaining between grooves (or less) resulted in good fragment breakout longitudinally in test QN0409A0. So in test QN0429A0 the grooves were varied so as to achieve metal thickness remaining values from 0.248 to 0.273-inch, to explore how thick metal remaining between grooves can be and still produce good fragments.

The inside longitudinal grooves were all made 0.100-inch deep. The outside longitudinal grooves were varied in depth to provide the range of values of metal thickness remaining between inside and outside grooves desired. The groove depths are summarized below.

| INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING BETWEEN GROOVES (inch) |
|---|---|---|
| 0.100 | 0.190 | 0.273 |
| 0.100 | 0.195 | 0.268 |
| 0.100 | 0.200 | 0.263 |
| 0.100 | 0.205 | 0.258 |
| 0.100 | 0.210 | 0.253 |
| 0.100 | 0.215 | 0.248 |

B. Circumferential Grooves

Metal thickness remaining between opposed grooves should be about the same as what worked in previous test. Metal thickness remaining values = 0.243-inch near booster end = 0.193-inch near non-booster end.

All inside circumferential grooves were 0.110-inch in depth, to prevent the inside non-booster-end corners of the fragments from breaking off. The outside circumferential grooves were made deep enough to reduce the metal tickness between the apexes of the opposed grooves to the value for which no fragment doubles had been recovered in test 6. The depths are presented below, groove-1 being nearest the booster end.

| GROOVE NUMBER | INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING BETWEEN GROOVES (inch) |
|---|---|---|---|
| 1 THRU 6 | 0.110 | 0.210 | 0.243 |
| 1 THRU 19 | 0.110 | 0.260 | 0.193 |

2.1.7.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENA

The test objective included characterizing the polar ejection angles and the velocities for the preformed fragments, and recovering a sample of each preformed-fragment size to determine if damage resulted during the detonation or from the fragment perforating the shroud. Fragment recovery, only, was desired, for the fireformed fragments. The test arena is illustrated in Figure 429-6, and photos appear in Figure 429-12.

2.1.7.3 DESCRIPTION OF TEST RESULTS

A. Fragment Quality

1. Fireformed Fragments

The longitudinal-groove designs were inadequate in that the metal remaining between the inside and outside opposed grooves was too thick. Example fragments are shown in Figures 429-4 and 429-5. Also a contributor to the poor longitudinal breakout (which is demonstrated in the following test) is the too-shallow depths of the inside groove.

The recovered fragments were of such poor quality that it was decided there was no useful information to be gained by weighing them.

2. Preformed Fragments

The fragment quality was excellent. The fragments exhibited some minor deformation from the explosive sweep, but lost no weight.

B. Fragment Velocity and Pattern - Preformed Fragments

A summary of the fragment velocity and polar ejection-angles for the hex-HIBAL fragments is presented in Figure 429-7. The fragment polar ejection angles are plotted as a function of the fragment center-of-length distance from the booster-end of the warhead in Figure 429-8. Measurements of the fragment-hit locations are presented in Figures 429-9, 10, 11. Photographs of the fragment pattern are presented in Figure 429-13.

CONCLUSIONS

1. Fireformed Warhead

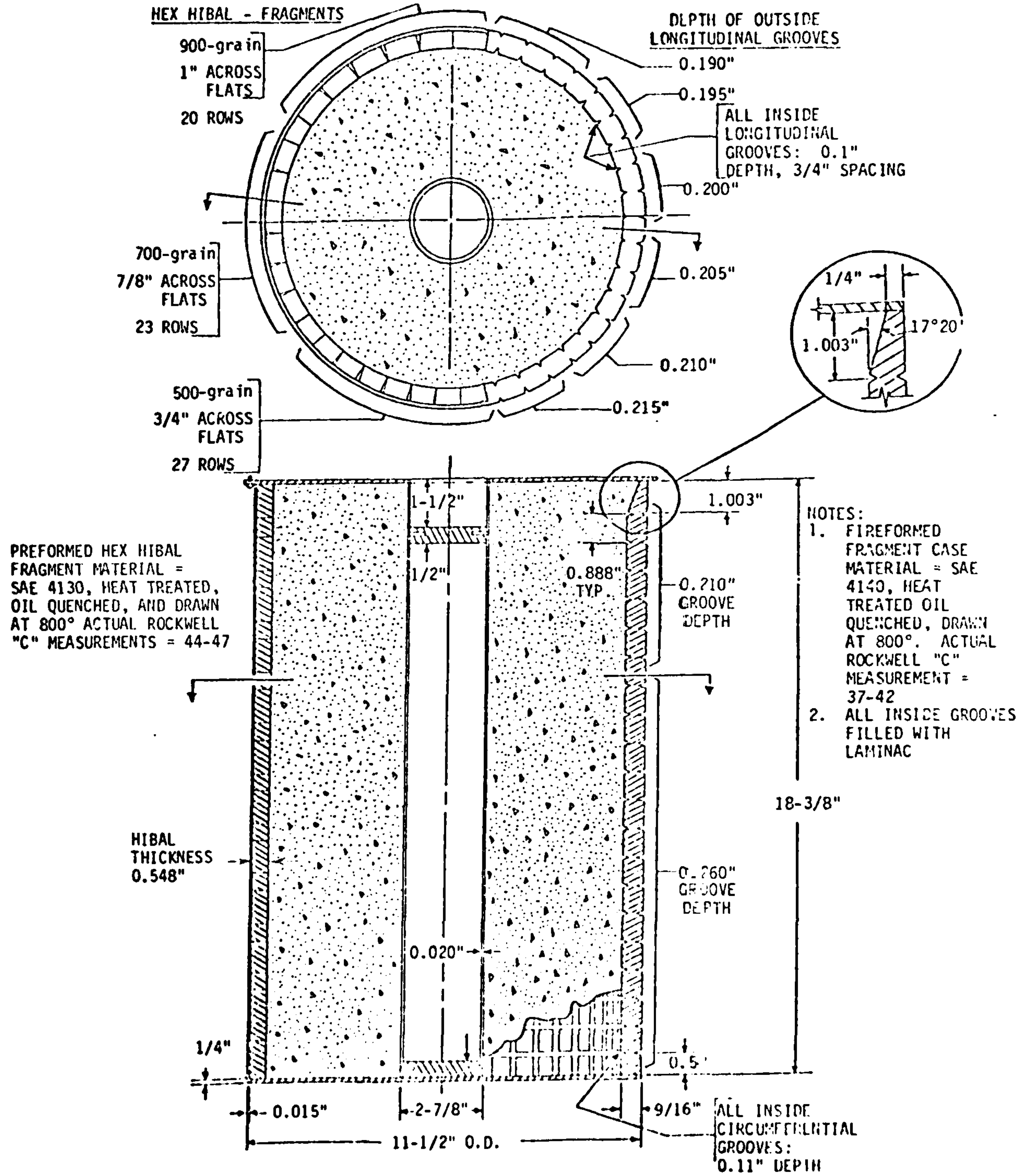
a. Opposed longitudinal grooves should have maximum of 0.240-inch remaining metal between the apexes of the opposed grooves to achieve proper breakout.

b. The circumferential grooves will have to be deeper, so as to reduce the metal thickness remaining between the apexes of the grooves to less than 0.193-inch.

c. The Celotex recovery may have contributed to fragment breakup in test QN0409A0. In the next test more witness sheets should be used to verify fragment lengthwise breakup prior to impact on the Celotex.

2. Preformed Warhead

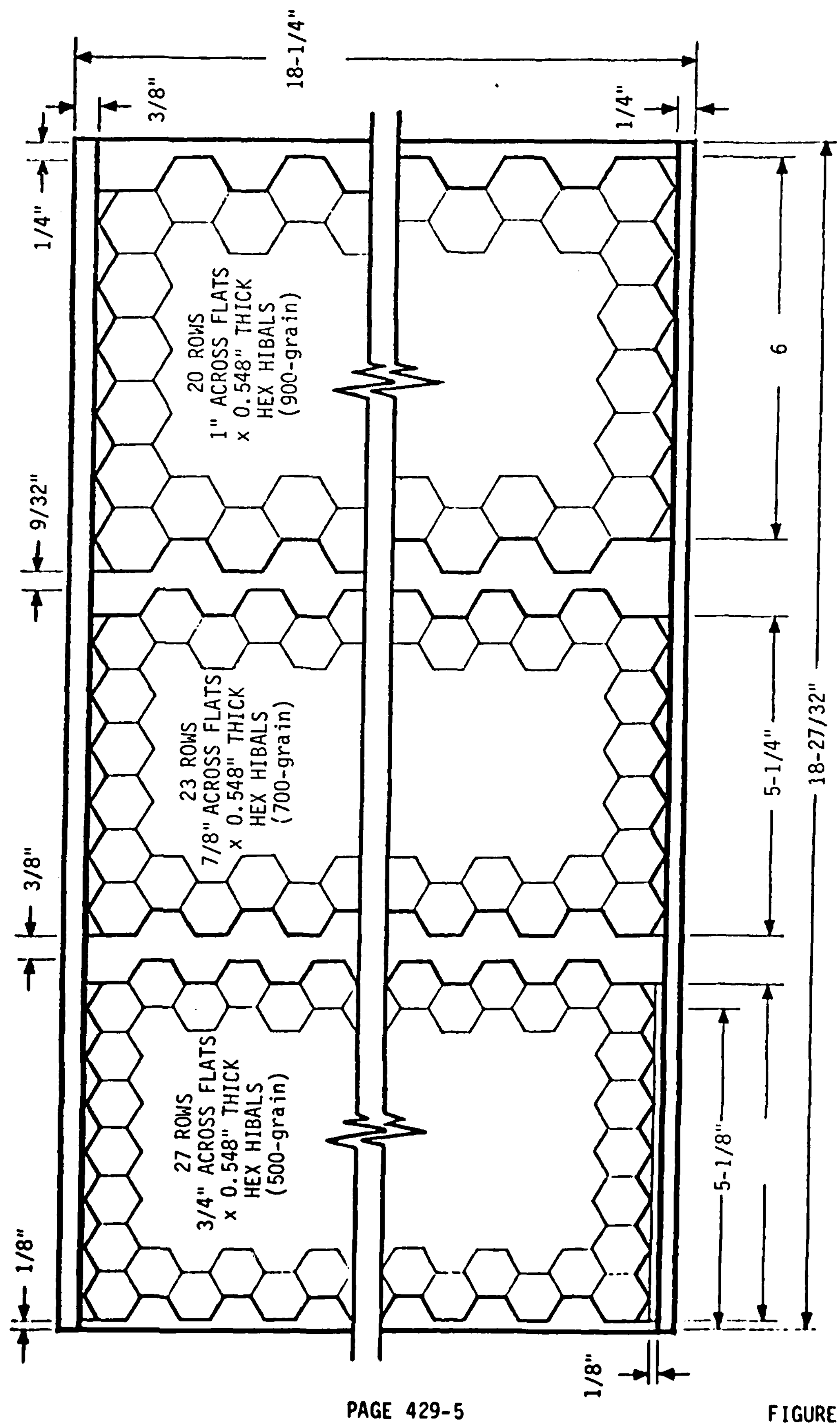
There is no need for further 115-inch diameter, 200-lb preformed-fragment warhead tests. The quality of the recovered fragments was excellent and the fragment velocity and pattern were within acceptable bounds.




WARHEAD DESIGN
TEST QN0429A0



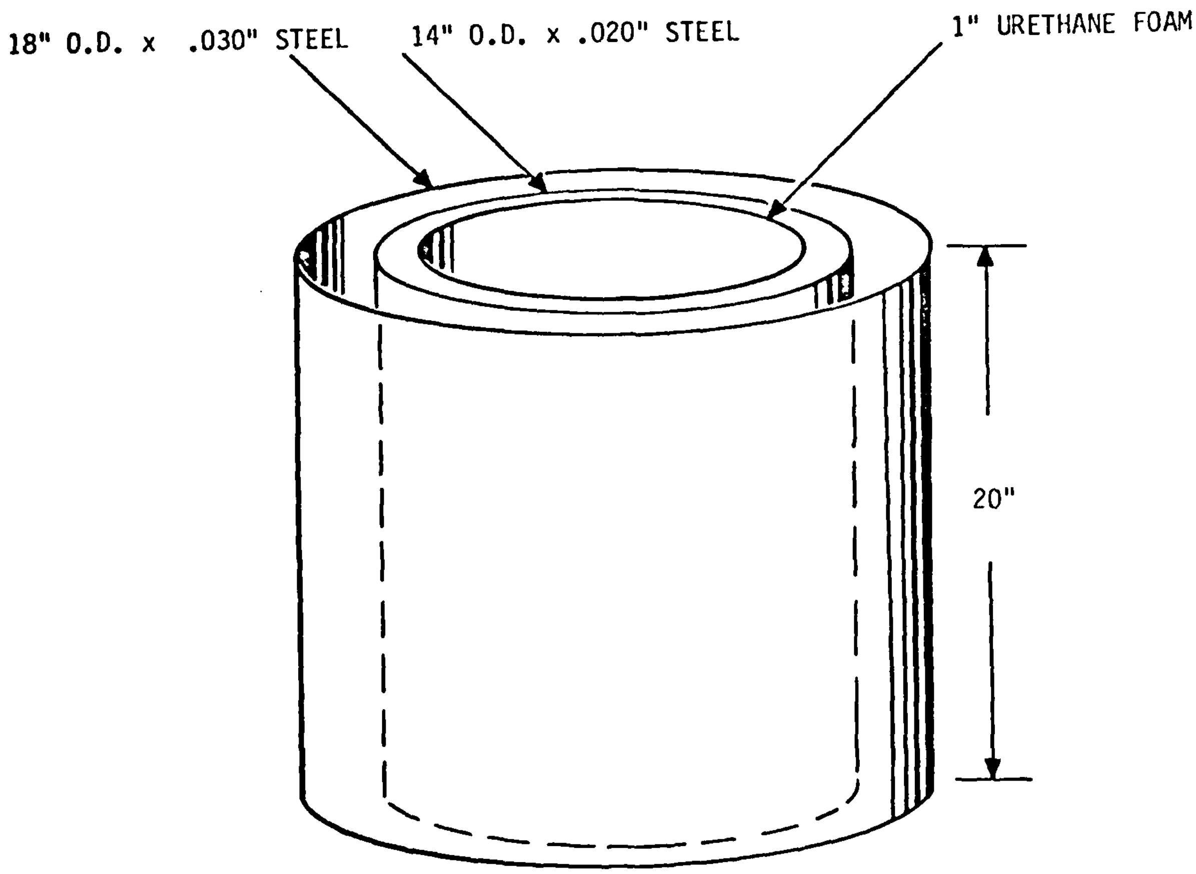
FIGURE 429-1




HEX HIBAL FRAGMENT PACKAGE
TEST QN0429A0



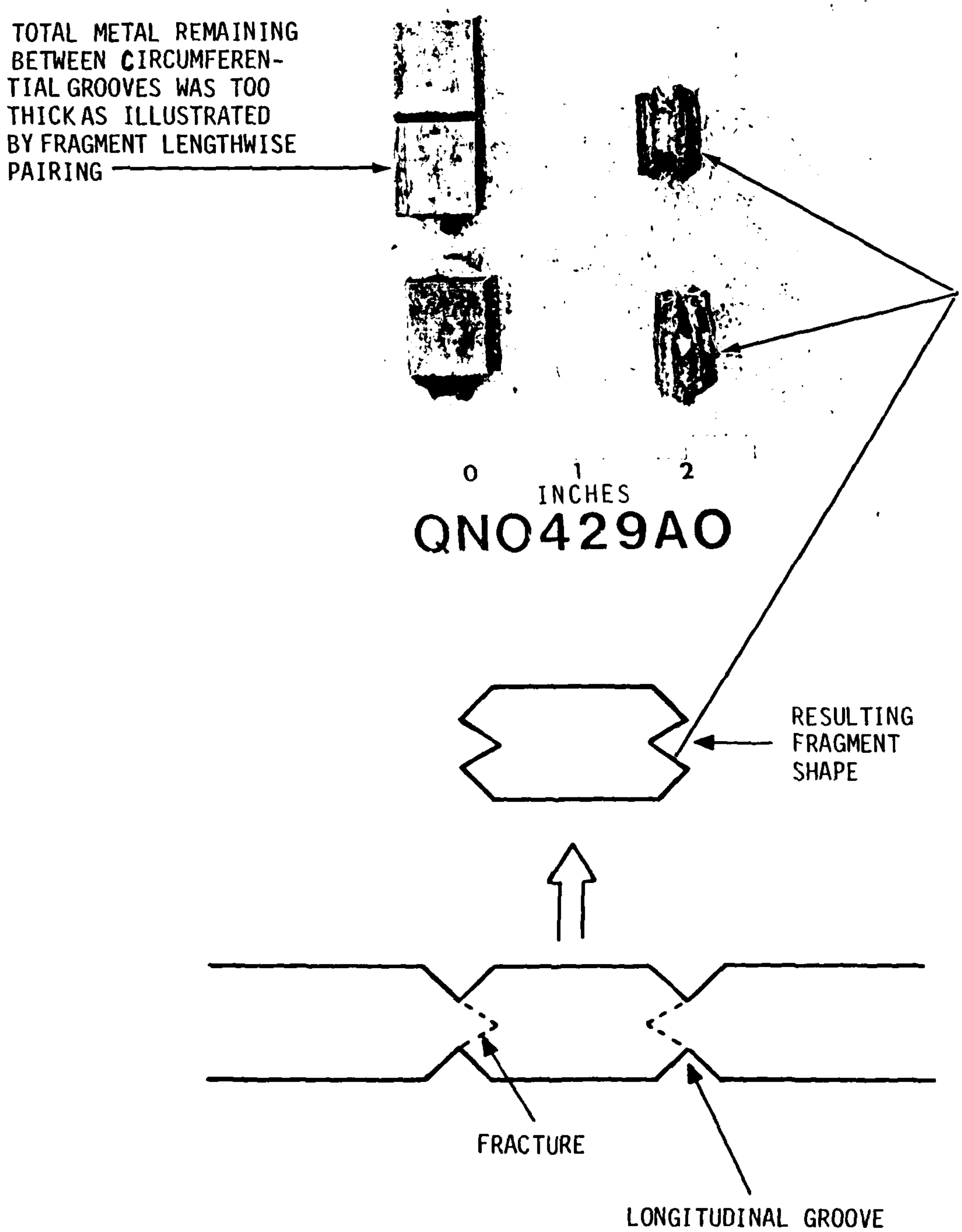
FIGURE 429-2




SHROUD FOR 11-1/2" O.D. 200-LB WARHEAD
TEST QN0429AJ

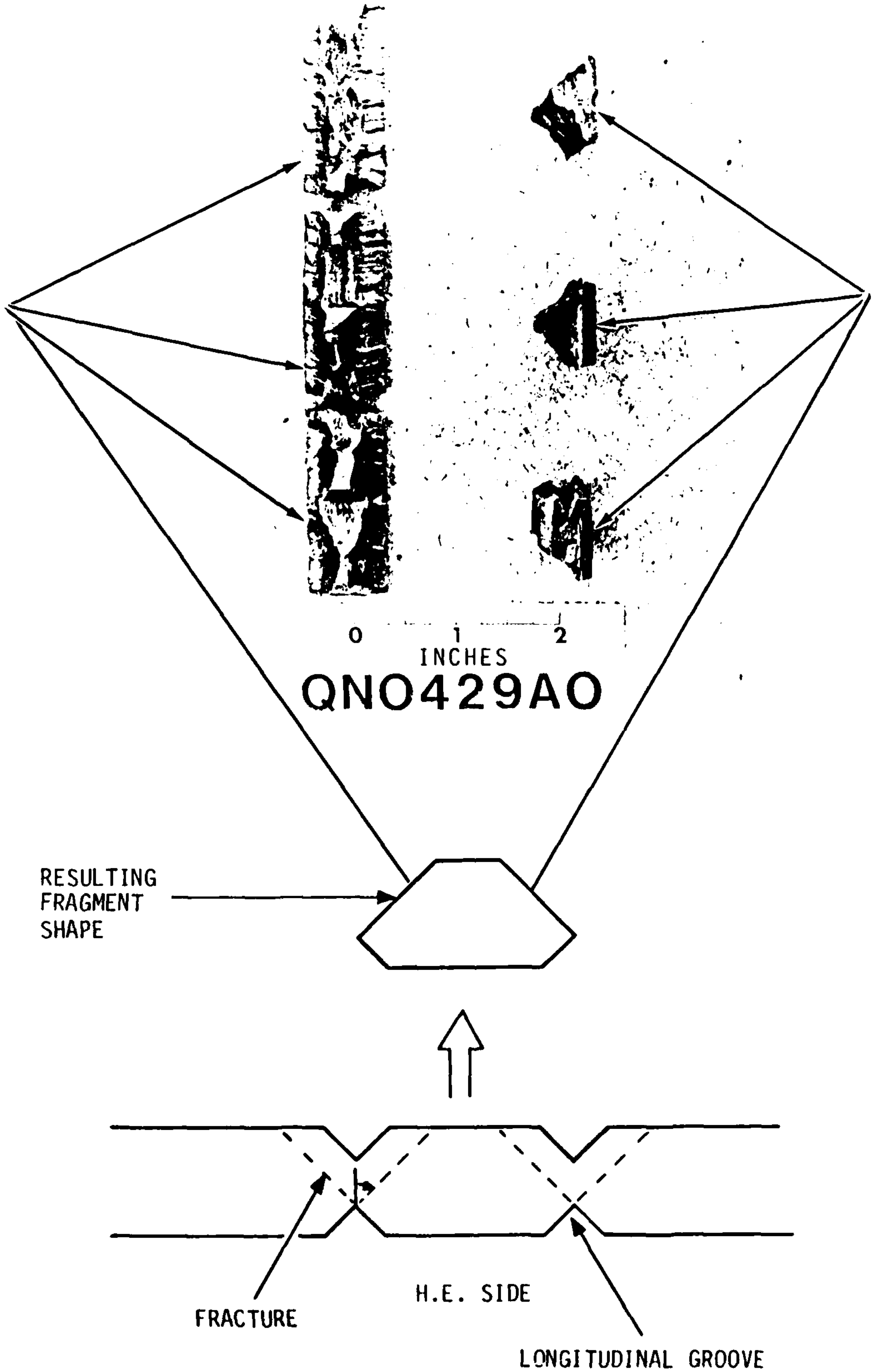


FIGURE 429-3




REDUCED-WEIGHT FRAGMENTS RESULTING WHEN THE METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.240" THROUGH 0.260"

EXAMPLE FRAGMENTS FROM TEST QN0429A0



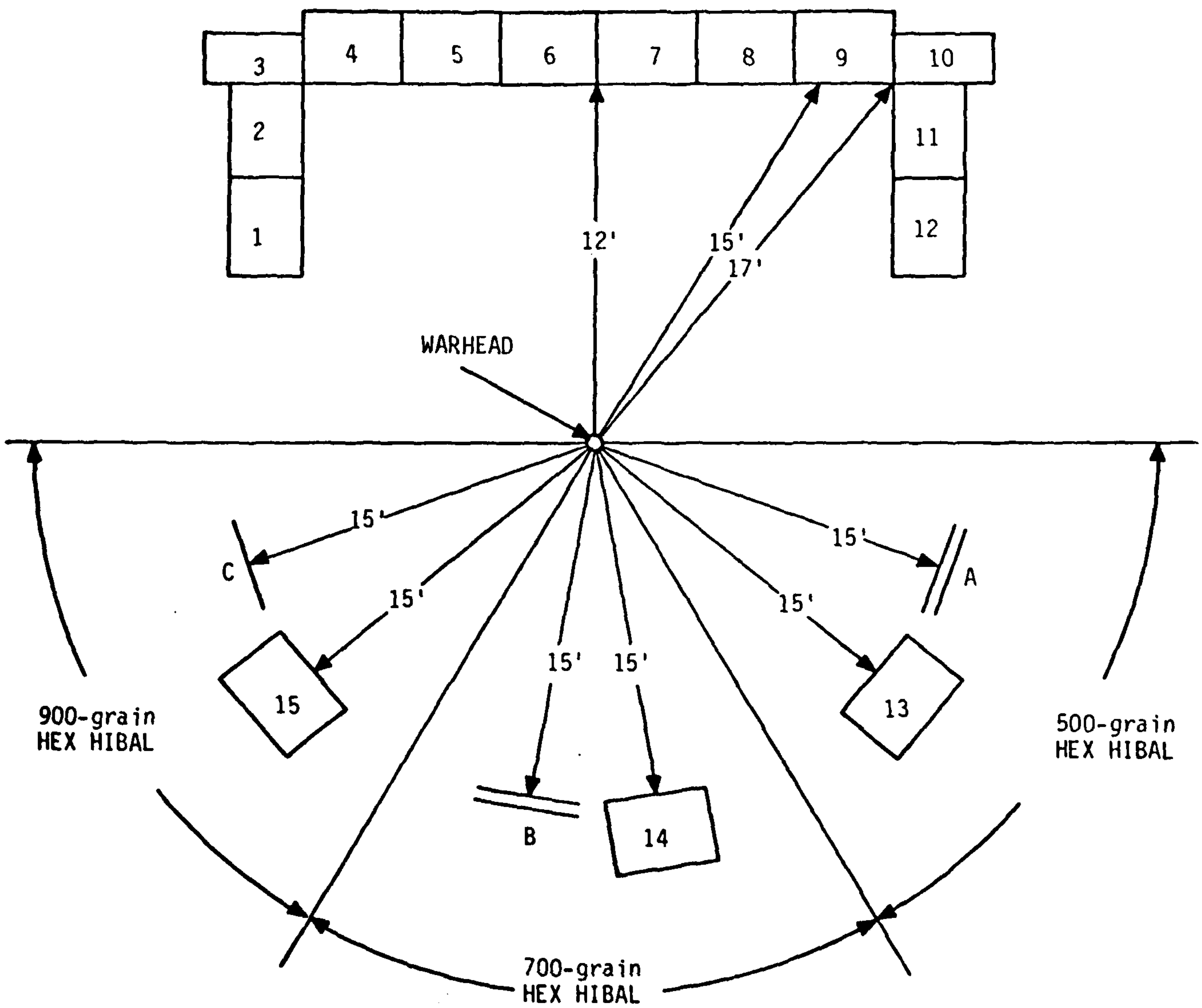

REDUCED-WEIGHT FRAGMENTS RESULTING WHEN METAL REMAINING
BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.280" OR MORE

EXAMPLE FRAGMENTS FROM TEST QN0429A0

FIGURE 429-5

TARGETS 1-15 = CELOTEX PACKS

TARGETS A, B, C = .105" STEEL WITNESS SHEETS, 12' HIGH
(NOTE: A, B = DOUBLE SHEETS WITH 6" SPACING)



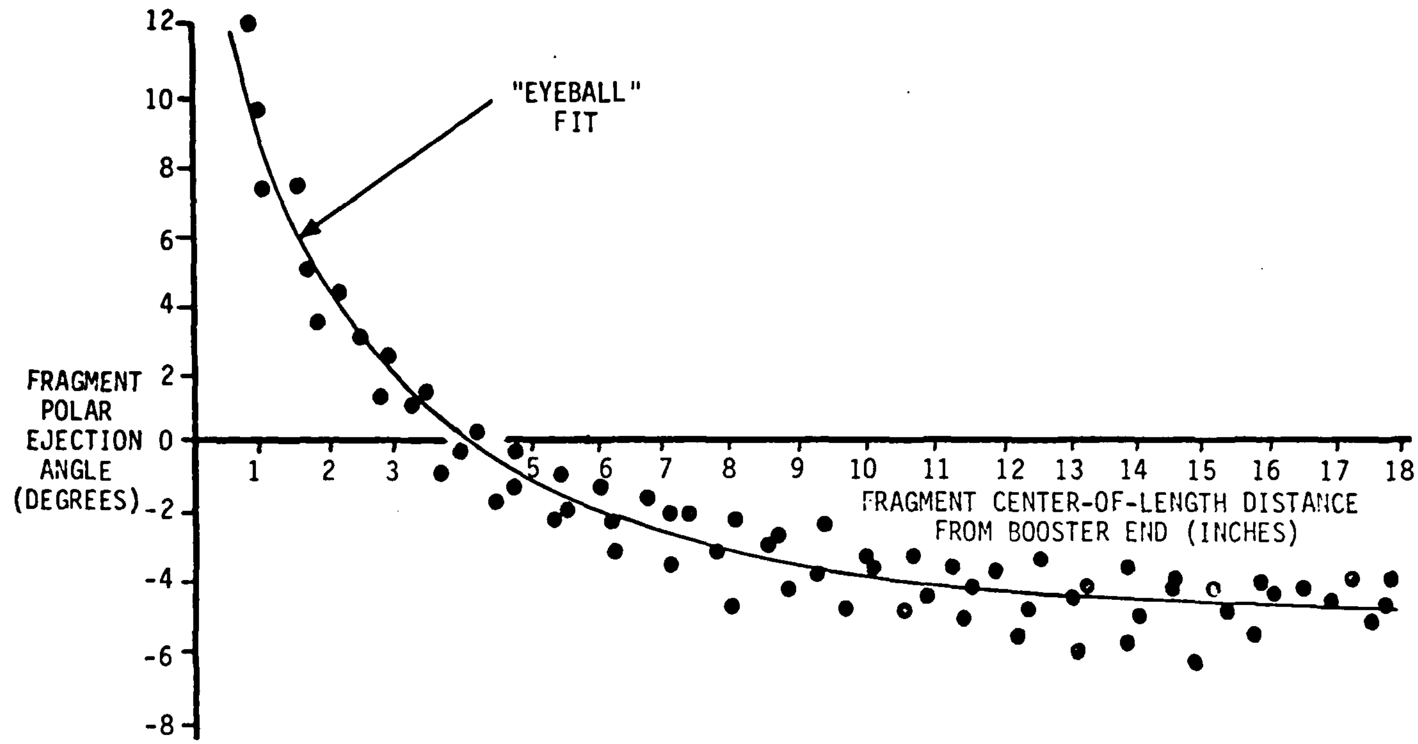

TEST QN0429A0

TEST QN0429A0

SUMMARY OF FRAGMENT VELOCITY AND POLAR EJECTION ANGLES FOR THE HEX-HIBAL FRAGMENTS

| FRAGMENT ROW | 500 GRAIN | 700 GRAIN | | 900 GRAIN |
|---|---|---|---|---|
| | POLAR ANGLE | POLAR ANGLE | VELOCITY AV. (AVG. 0-15½') | POLAR ANGLE |
| 1 | +12.0° | + 9.5° | 4100 | + 7.3° |
| 2 | + 7.3° | + 5.0° | 4200 | + 3.4° |
| 3 | + 4.2° | + 2.5° | 4300 | + 1.2° |
| 4 | + 2.3° | + 1.0° | 4500 | - 1.0° |
| 5 | + 1.3° | - 0.3° | 4850 | - 1.8° |
| 6 | + 0.1° | - 1.4° | 4500 | - 2.3° |
| 7 | + 0.3° | - 2.0° | 5000 | - 3.2° |
| 8 | - 1.1° | - 2.3° | 5000 | - 3.6° |
| 9 | - 1.4° | - 2.2° | 5100 | - 4.4° |
| 10 | - 1.7° | - 3.2° | 4850 | - 4.2° |
| 11 | - 2.1° | - 3.1° | 5100 | - 4.9° |
| 12 | - 2.4° | - 3.9° | 5100 | - 5.0° |
| 13 | - 2.9° | - 3.8° | 5300 | - 5.2° |
| 14 | - 2.6° | - 4.5° | 5100 | - 5.7° |
| 15 | - 3.5° | - 4.3° | 5300 | - 6.1° |
| 16 | - 3.4° | - 5.0° | 5450 | - 5.2° |
| 17 | - 3.8° | - 4.6° | 5450 | - 6.5° |
| 18 | - 3.8° | - 5.0° | 5450 | - 5.7° |
| 19 | - 3.5° | - 4.4° | 5450 | |
| 20 | - 4.5° | - 5.0° | 5450 | - 5.3° |
| 21 | - 3.8° | - 4.5° | 5300 | |
| 22 | - 4.3° | - 4.8° | 5300 | |
| 23 | - 4.4° | - 4.9° | 5000 | |
| 24 | - 4.2° | | | |
| 25 | - 4.3° | | | |
| 26 | - 4.1° | | | |
| 27 | - 4.1° | | | |

11-1/2" O.D., 9/16" WALL




FRAGMENT POLAR EJECTION ANGLE AS A FUNCTION OF THE FRAGMENT CENTER-OF-LENGTH DISTANCE FROM THE BOOSTER END OF THE WARHEAD, TEST QN0429A0



FIGURE 429-8

TEST QN0429A0

VERTICAL MEASUREMENTS (INCHES)* OF FRAGMENT HIT LOCATIONS ON WITNESS SHEET

| FRAGMENT ROW NUMBER | 700-gr FRAGMENT WITNESS SHEET | | |
|---|---|---|---|
| | COLUMN 1 | COLUMN 2 | COLUMN 3 |
| 1 | | +29 | |
| 2 | +14 | | +14 |
| 3 | | + 5½ | |
| 4 | + 1 | | - 1½ |
| 5 | | - 5 | |
| 6 | - 9½ | | - 9 |
| 7 | | 12 | |
| 8 | -12½ | | -14½ |
| 9 | | -14 | |
| 10 | -18 | | -18 |
| 11 | | -18½ | |
| 12 | -20½ | | -22 |
| 13 | | -22 | |
| 14 | -24 | | -26 |
| 15 | | -25 | |
| 16 | -28 | | --- |
| 17 | | -27½ | |
| 18 | -29 | | -30 |
| 19 | | -28½ | |
| 20 | -30 | | -32 |
| 21 | | -30½ | |
| 22 | -30½ | | -33½ |
| 23 | | -33 | |

*Coordinates measured from the top of warhead aimline.



FIGURE 429-9

TEST QN0429A0

VERTICAL MEASUREMENTS (INCHES)* OF FRAGMENT HIT LOCATIONS
ON WITNESS SHEETS

| FRAGMENT ROW NUMBER | 500-gr FRAGMENT WITNESS SHEET | | | |
|---|---|---|---|---|
| | COLUMN 1 | COLUMN 2 | COLUMN 3 | COLUMN 4 |
| 1 | | +37 | | +37½ |
| 2 | | | +21½ | |
| 3 | | +11 | | +11 |
| 4 | + 4½ | | + 4 | |
| 5 | | + ½ | | + ½ |
| 6 | | | - 4 | |
| 7 | | - 5½ | | - 6 |
| 8 | | | - 9 | |
| 9 | | -11 | | -10 |
| 10 | | | -12 | |
| 11 | | -14½ | | -13½ |
| 12 | | | -15½ | |
| 13 | | -17½ | | -18 |
| 14 | | | -17½ | |
| 15 | | -21½ | | -20½ |
| 16 | -21 | | -21½ | |
| 17 | | -24 | | -22½ |
| 18 | -23 | | -25 | |
| 19 | | -24 | | -23½ |
| 20 | -27 | | -28 | |
| 21 | | -26 | | -26 |
| 22 | -27½ | | -28½ | |
| 23 | | -29½ | | -28½ |
| 24 | | | -29 | |
| 25 | | -30 | | -30 |
| 26 | | | 30 | |
| 27 | | -31½ | | -30 |

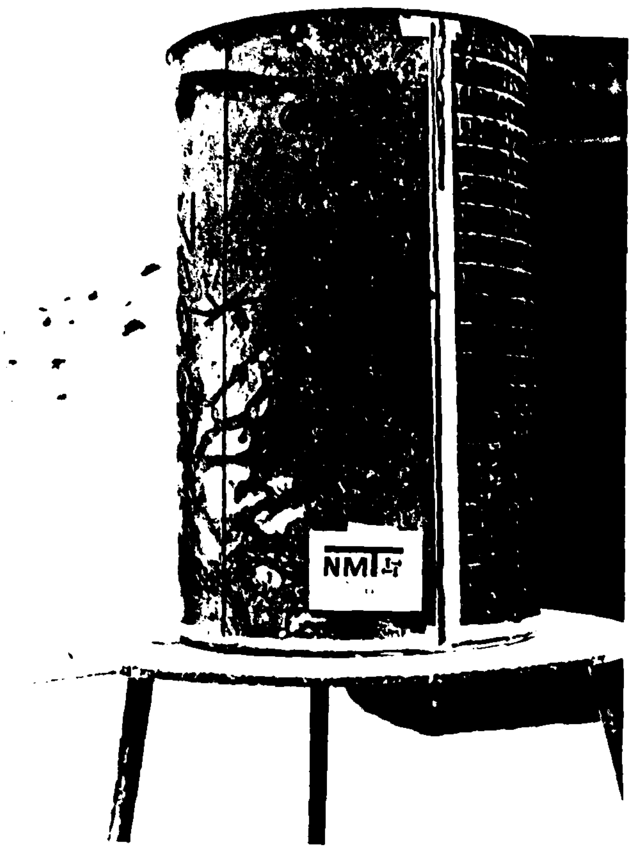
*Coordinates measured from the top of warhead aimline.

TEST QN0429A0

VERTICAL MEASUREMENT (INCHES)* OF FRAGMENT HITS ON WITNESS SHEET

| FRAGMENT ROW NUMBER | 900-gr FRAGMENT WITNESS SHEET | | |
|---|---|---|---|
| | COLUMN 1 | COLUMN 2 | COLUMN 3 |
| 1 | | +22 | |
| 2 | + 9 | | + 8½ |
| 3 | | + 1 | |
| 4 | - 6 | | - 7½ |
| 5 | | -10 | |
| 6 | -13 | | -12½ |
| 7 | | -16½ | |
| 8 | -19½ | | -17½ |
| 9 | | -22 | |
| 10 | -22 | | -22½ |
| 11 | | -25 | |
| 12 | -27½ | | -25 |
| 13 | | -28 | |
| 14 | -30½ | | -30 |
| 15 | | -32½ | |
| 16 | -31 | | -30 |
| 17 | | -35½ | |
| 18 | -33 | | -34½ |
| 19 | | | |
| 20 | -33½ | | -35 |

*Vertical coordinates from top of warhead aimline.

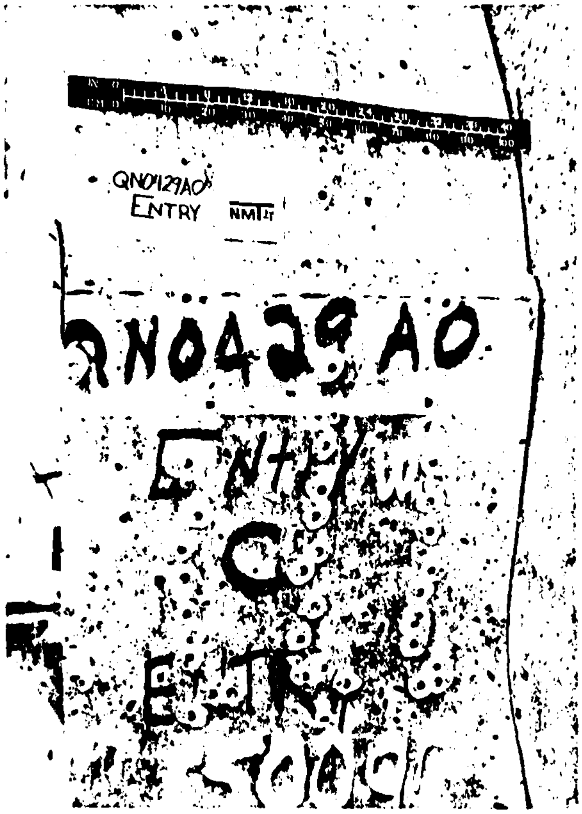



WARHEAD PRIOR TO
PLACEMENT
OF SHROUD

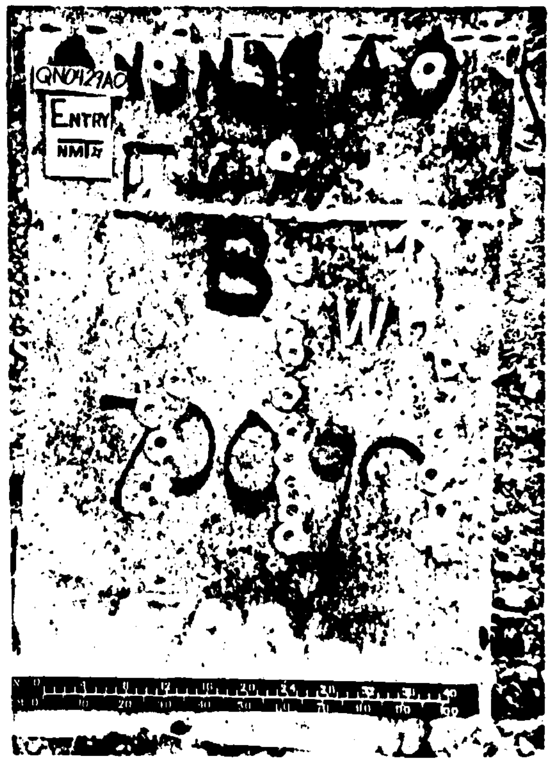
TEST ARENA



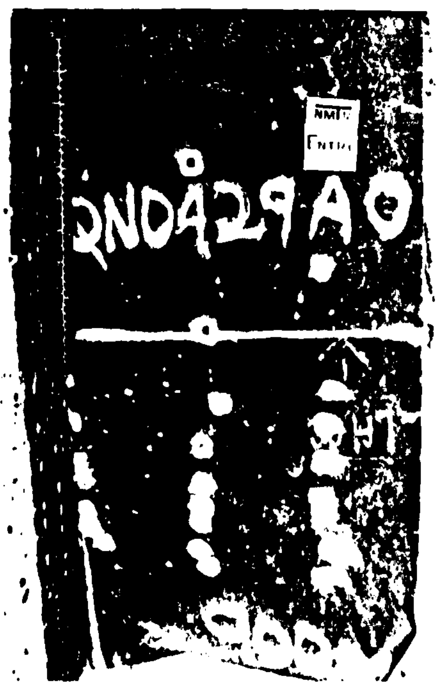
FIGURE 429-12




500-GRAIN HIBALS




700-GRAIN HIBALS



900-GRAIN HIBALS

WITNESS SHEETS
FROM TEST QN0429A0



FIGURE 429-13

TEST QN0514A0

11.5", 135-LB PREFORMED FRAGMENT/FIREFORMED FRAGMENT COMBINATION WARHEAD

### 2.1.8 TEST 7, QN0514A0

#### 2.1.8.1 DESIGN SUMMARY AND RATIONALE

This warhead was partly fireformed fragments and partly preformed fragments. The basic design characteristics of the warhead (Figures 514-1, 2, 3) were:

| | |
|---|---|
| OUTSIDE DIAMETER: | 11.5-inch |
| INSIDE DIAMETER: | 2.875-inch |
| LENGTH: | 14.0-inch |
| CASE THICKNESS: | 0.5-inch |
| CASE MATERIAL: | |
| Preformed fragments: | SAE 4130, (RC40-42) |
| Fireformed fragments: | SSS 100, (RC-42), HY-80, (RC40-43) |
| WARHEAD WEIGHT: | 135-lb |
| SHROUD: | Two steel skins, 0.020-inch inside, 0.030-inch outside, with 1-inch urethane foam insulation between warhead and inner shroud |

The preformed hex-HIBAL fragments were all 0.485-inch thick, and were the following sizes: 13/16-inch across flats (500-grain); 15/16-inch across flats (700-grain); 1-1/16-inch across flats (900-grain). The fragments were potted in laminac with a 0.015-inch outside skin.

The fireformed fragment case was grooved circumferentially to provide 15 rows of equal-length fragments, each 0.867-inch long. The spacing between the longitudinal grooves was 0.625-inch, which provided for a theoretical fragment weight of 540-grains (before any weight loss due to fireforming).

Two different materials, SSS-100 and HY-80, were tested in the fireformed portion of the warhead to determine if the opposed grooving technique was sensitive to choice of alloy.*

For the HY-80, both the longitudinal and circumferential groove-depths were selected which had been successful for the SAE 4130 alloy in test 5.

For the SSS-100, with the metal remaining between the longitudinal opposed grooves being held approximately constant, the internal and external groove depths were varied. Circumferential grooves for the SSS-100 were made slightly deeper on the non-booster end than the HY-80 to fully insure that the resulting circumferential groove breakout at that end of the warhead would avoid the creation of doublets. The grooves

* Flat plates of each material were circumferentially grooved, formed to the desired radius of curvature in a press, longitudinally grooved, and then welded together to form the warhead case.

at the booster end were made slightly shallower than those used with HY-80, to determine if doublets would occur at the booster end of the warhead.

HY-80 GROOVE DETAILS

| LONGITUDINAL | | | CIRCUMFERENTIAL | | | |
|---|---|---|---|---|---|---|
| INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING (inch) | GROOVE NUMBER (inch) | INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING (inch) |
| 0.100 | 0.160 | 0.240 | 1,2 | 0.100 | 0.120-0.140 | 0.260-0.280 |
| 0.100 | 0.170 | 0.230 | 3,4,5 | 0.100 | 0.180-0.200 | 0.200-0.220 |
| ----- | ----- | ----- | 6-16 | 0.100 | 0.220-0.240 | 0.160-0.180 |

SSS-100 GROOVE DETAILS

| LONGITUDINAL | | | CIRCUMFERENTIAL | | | |
|---|---|---|---|---|---|---|
| INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING (inch) | GROOVE NUMBER (inch) | INSIDE DEPTH (inch) | OUTSIDE DEPTH (inch) | METAL REMAINING (inch) |
| 0.130 | 0.130 | 0.240 | 1,2 | 0.100 | 0.100-0.120 | 0.280-0.300 |
| 0.156 | 0.104 | 0.240 | 3-8 | 0.100 | 0.200-0.220 | 0.200-0.180 |
| 0.104 | 0.156 | 0.240 | 9-16 | 0.100 | 0.240-0.260 | 0.140-0.160 |
| 0.140 | 0.140 | 0.220 | ------ | -------- | ------------ | ----------- |
| 0.140 | 0.130 | 0.230 | ------ | -------- | ------------ | ----------- |

The shroud (Figure 514-4) is the same as was used in the previous 11.5-inch diameter warheads.

### 2.1.8.2 DESCRIPTION OF TEST OBJECTIVES AND TEST ARENA

For the fireformed-fragment portion of the warhead the primary objective was fragment recovery. In addition, witness sheets were placed between each Celotex pack to provide evidence of fragment doubles, because previous firings had indicated that some breakup of doublets into singles may have occurred during impact with the Celotex.

For the preformed hex-HIBAL portion of the warhead, fragment velocity and pattern were the objectives.

The test arena is illustrated in Figure 514-8, and photographs of the arena are presented in Figures 514-14 and 514-15.

2.1.8.3 DESCRIPTION OF TEST RESULTS.

A. Fragment Quality

1. Fireformed Fragments

a. HY-80 Steel

The fragment breakout along the longitudinal grooves was good for both choices of longitudinal grooving. However, breakout along the circumferential grooves were not as good in that fragment multiples (lengthwise) occasionally occurred everywhere except adjacent to the booster end. (The booster-end row of fragments were good.) Example fragments are presented in Figure 514-6.

b. SSS-100

The fragment breakout along the longitudinal grooves was excellent for every choice but one - the choice which had 0.104-inch deep inside grooves and 0.156-inch-deep outside grooves, wherein fragment scabbing and partial fragments were prevalent, as shown in Figure 514-9. Some fragment lengthwise multiples were recovered for all choices of circumferential groove depths, indicating that depths of grooves were less than required. Examples are shown in Figure 514-15.

The fragments were not weighed because the weight of strings of fragments are meaningless.

2. Preformed Fragments

Witness sheet data indicated that no breakup of the preformed fragments occurred.

B. Fragment Pattern and Velocity

1. Fireformed Fragments

This test was not designed to acquire pattern and velocity data for fireformed fragment.

2. Preformed Fragments

A summary of the hex-HIBAL-fragment polar-ejection angles and velocities is presented in Figure 514-9. The hex-HIBAL fragment polar ejection angles are plotted as a function of the fragment center-of-length distance from the booster end of the warhead in Figure 514-10. Tables of the fragment hit locations are presented in Figures 514-11, 12, 13. Photographs of the fragments pattern are presented in Figure 514-16.

## C. Conclusions

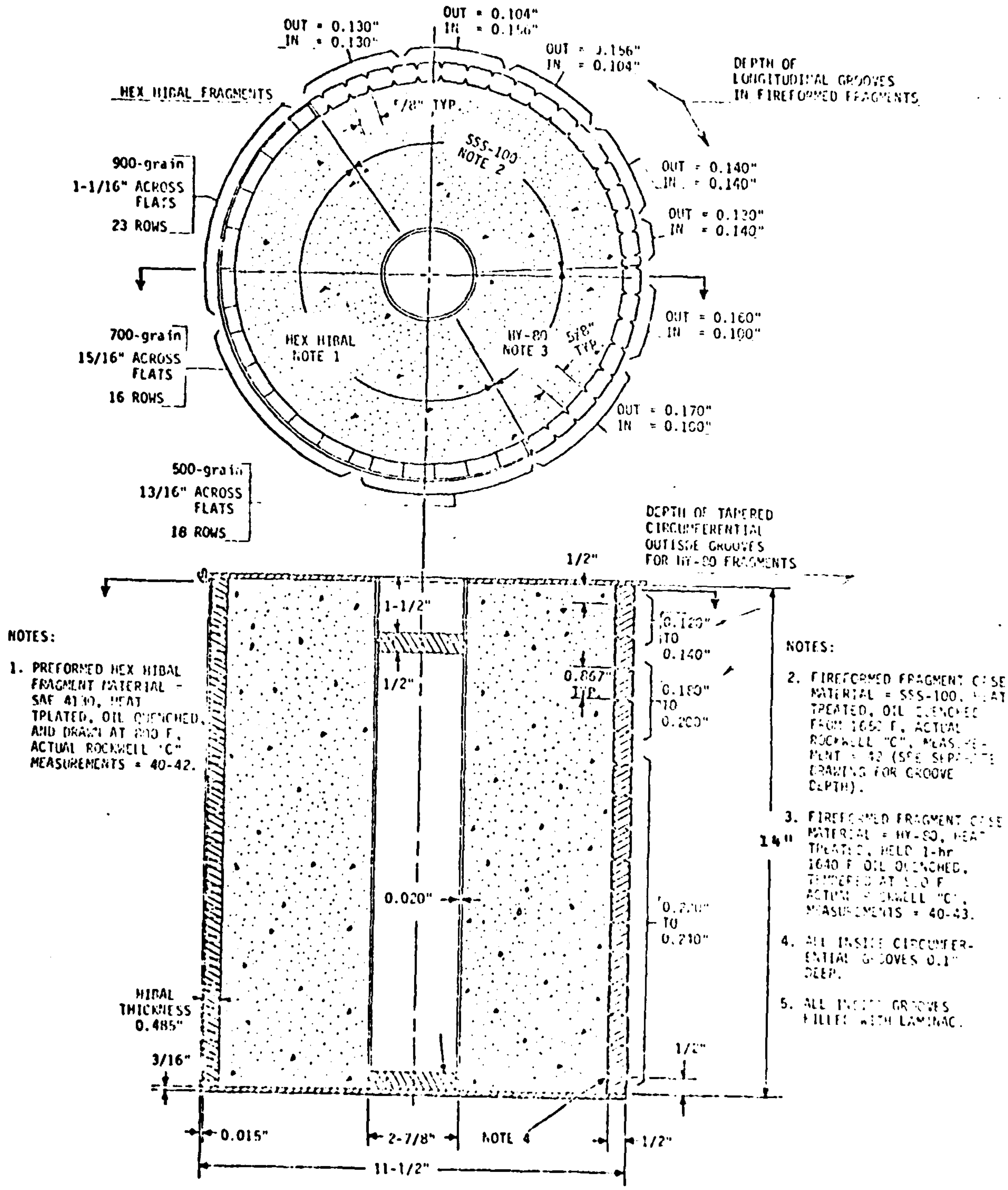
### 1. Fireformed Fragment Warhead

a. The design requirements for achieving proper fireforming of fragments with opposed longitudinal grooves have been well defined. The metal remaining between the apexes of the longitudinal grooves should be between 0.200 and 0.240-inch.

b. The metal remaining between the apexes of the circumferential grooves must be less than 0.140-inch, probably about 0.100-inch, but the exact value remains to be demonstrated.

### 2. Preformed Fragment Warhead

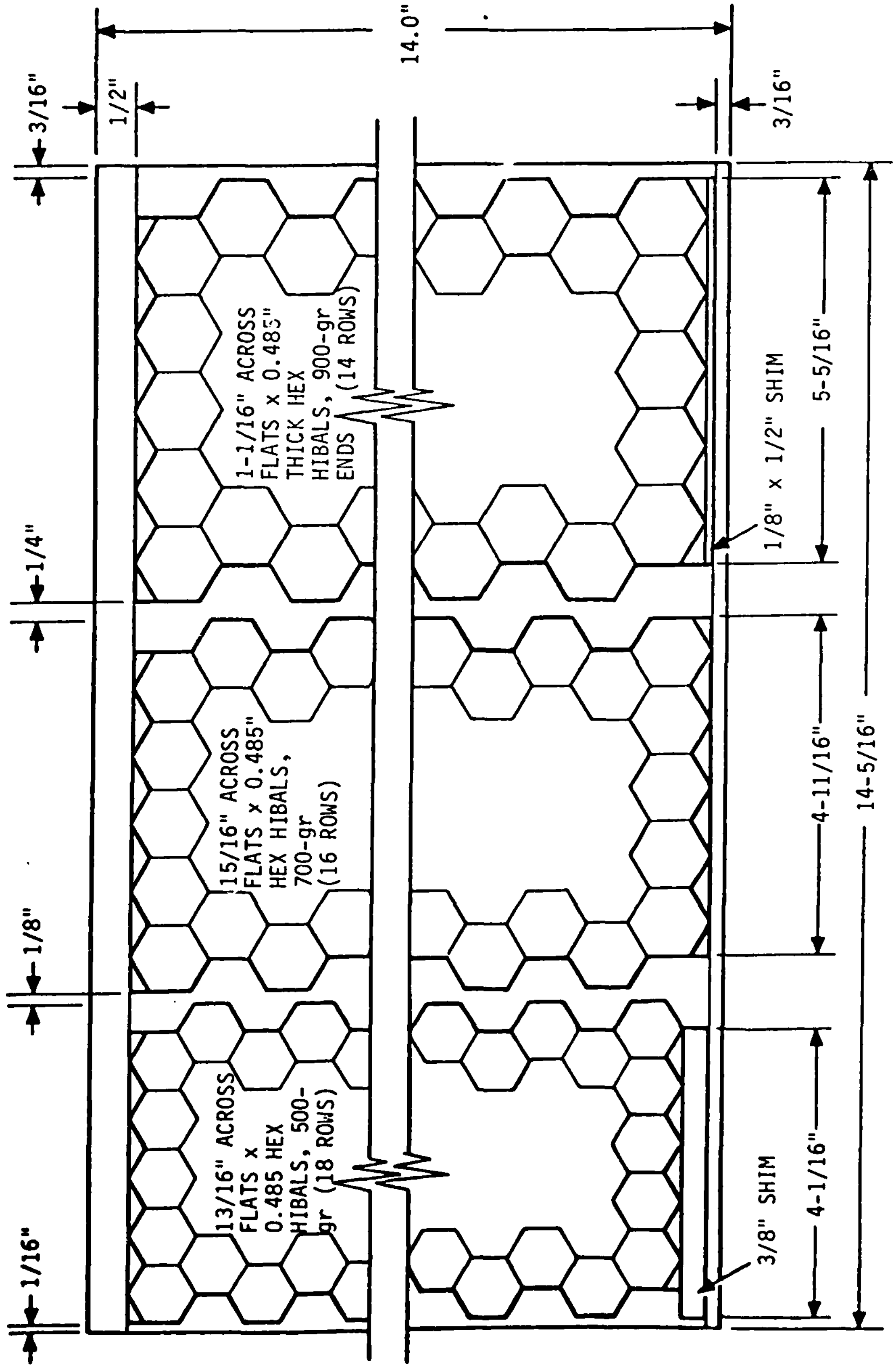
There is no need fo further 11.5-inch diameter, 135-lb warhead tests. Fragment quality, velocity and pattern characteristics were all within the desired bounds.




WARHEAD DESIGN
TEST QN0514A0



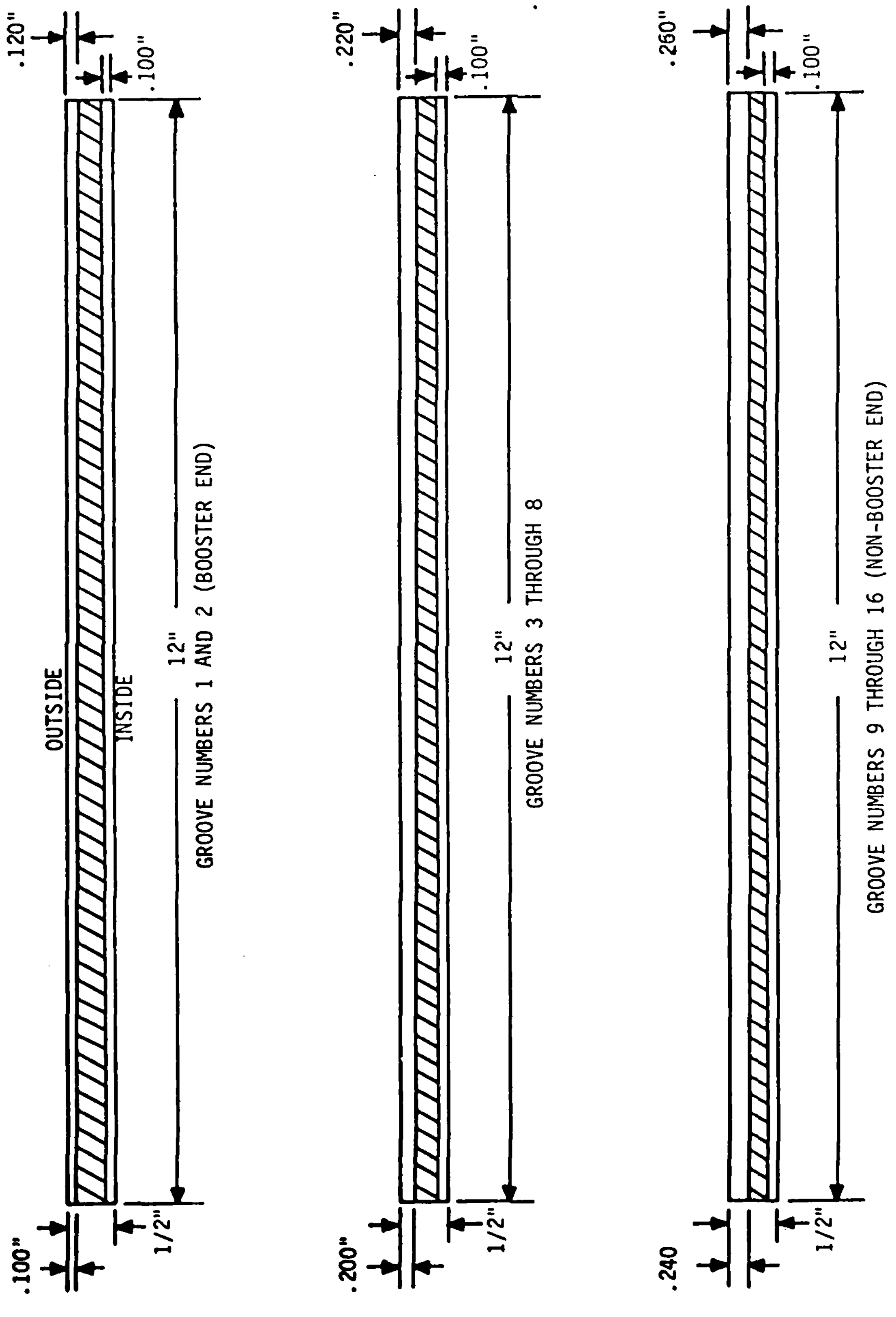
FIGURE 514-1




HEX HIBAL DETAILS
TEST QN0514A0



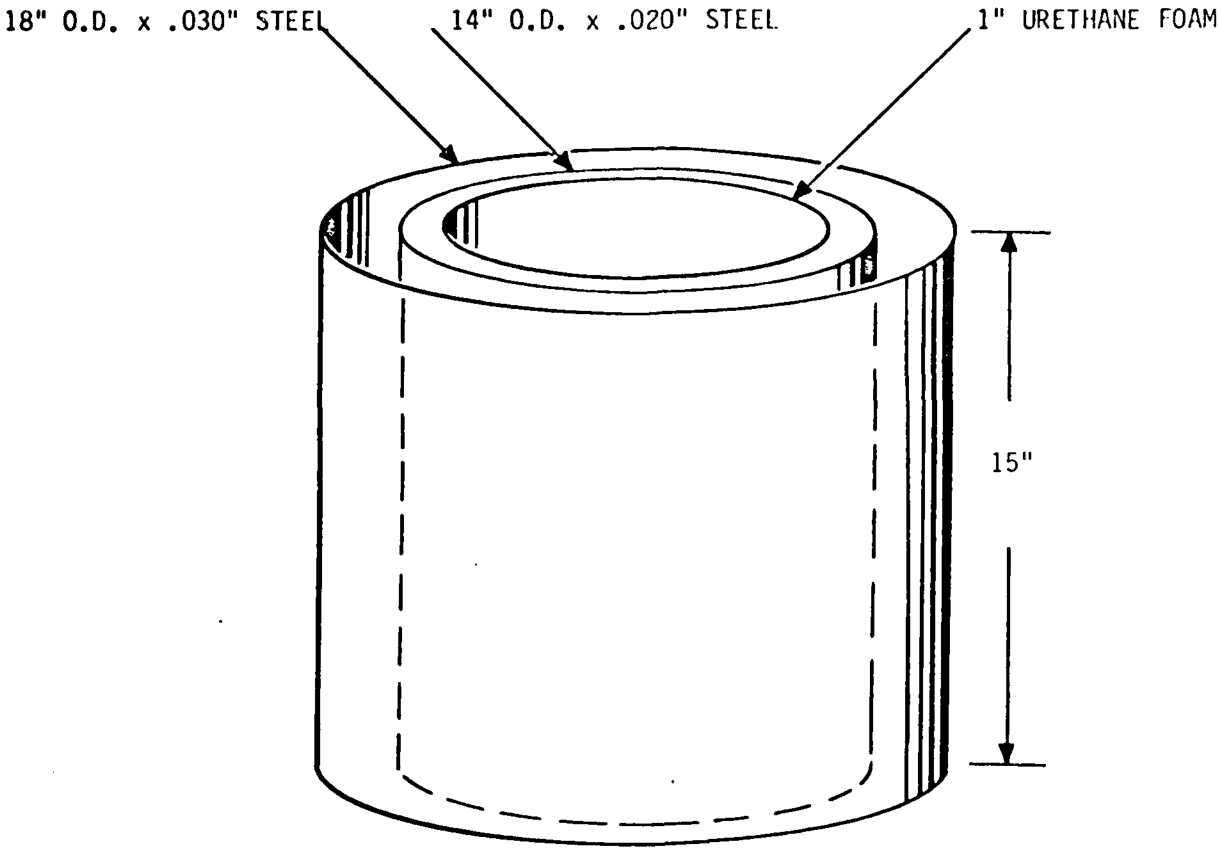
FIGURE 514-2




CIRCUMFERENTIAL GROOVE DETAILS FOR SSS-100 STEEL



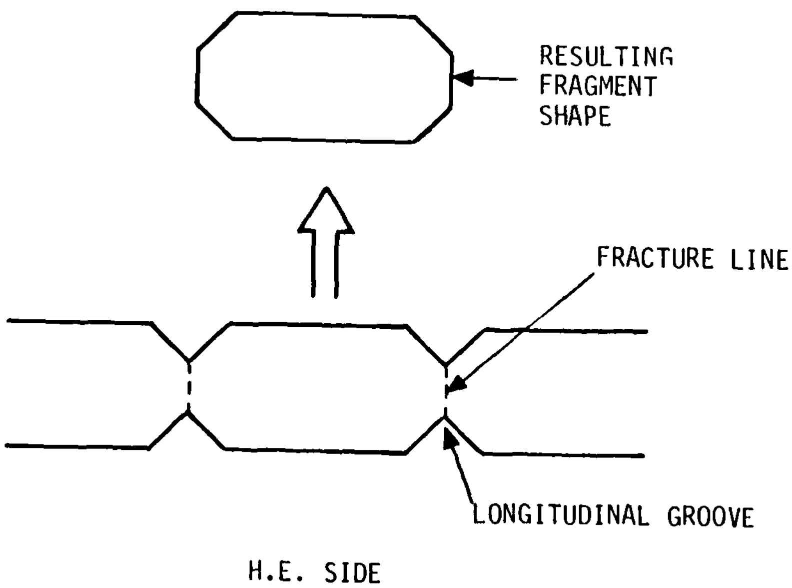
FIGURE 514-3




SHROUD FOR 11-1/2" O.D., 135-LB WARHEAD

TEST QN0514A0

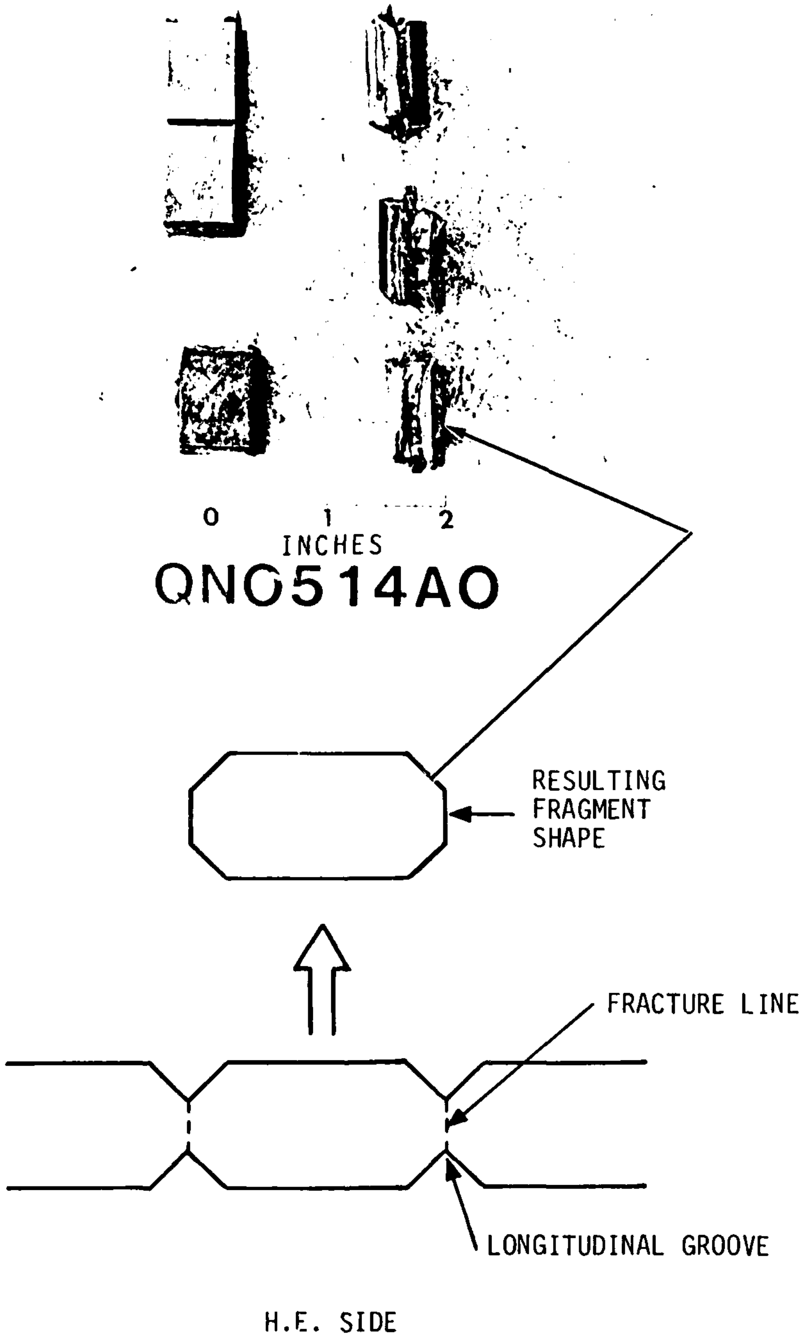

QNO514AO




FRAGMENT SHAPE RESULTING IN SSS-100 WHEN THE METAL REMAINING BETWEEN LONGITUDINAL INSIDE AND OUTSIDE GROOVES IS .220", AND THE INSIDE AND OUTSIDE GROOVE DEPTHS ARE EQUAL



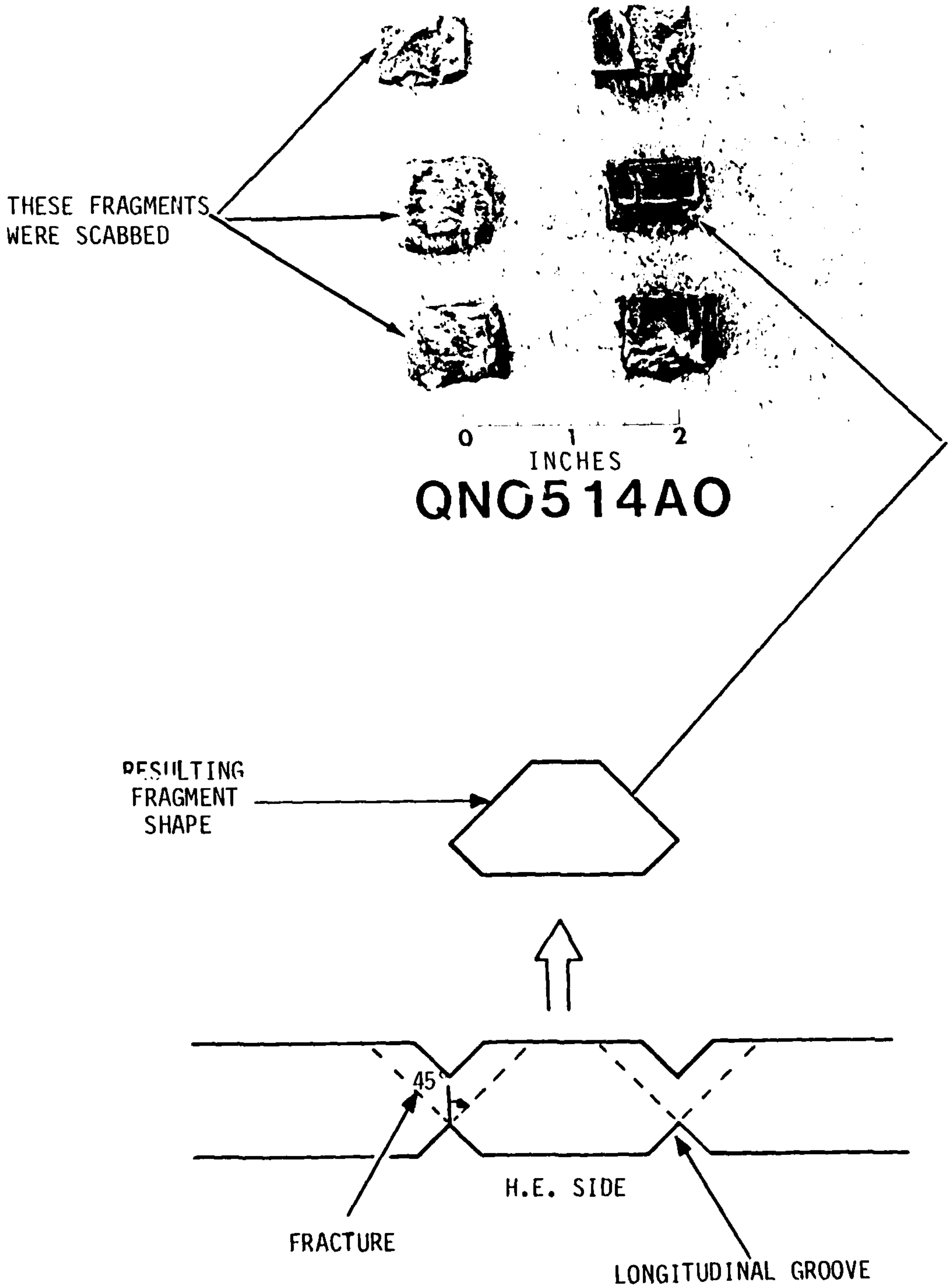
FIGURE 514-5




FRAGMENT SHAPE RESULTING IN HY-80 WHEN THE METAL REMAINING BETWEEN LONGITUDINAL INSIDE AND OUTSIDE GROOVES WAS 0.230", AND THE INSIDE LONGITUDINAL GROOVE WAS .100" DEEP



FIGURE 514-6



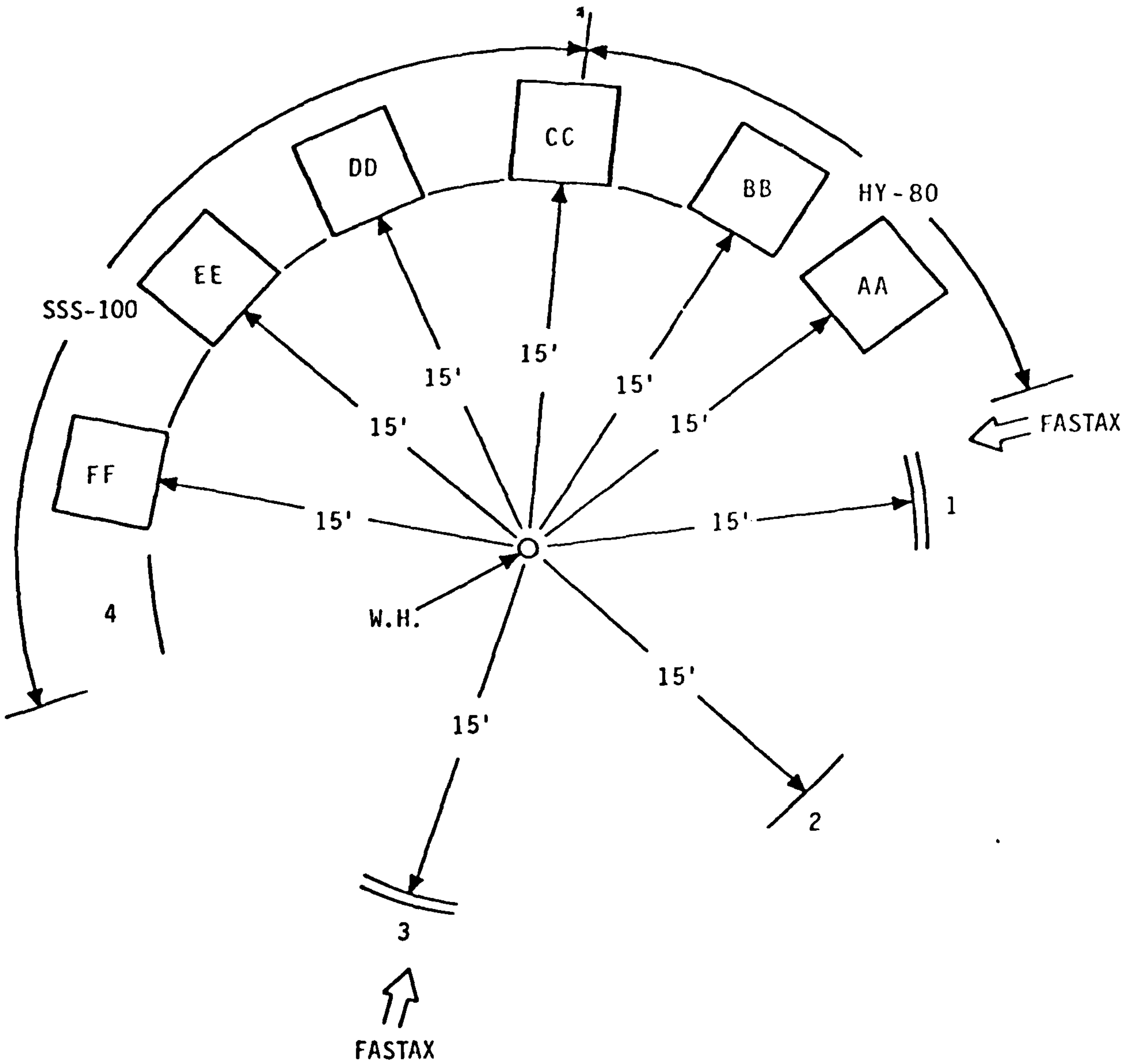

REDUCED-WEIGHT FRAGMENTS RESULTING IN SSS-100 WHEN METAL REMAINING BETWEEN INSIDE AND OUTSIDE LONGITUDINAL GROOVES WAS 0.240", AND INSIDE LONGITUDINAL GROOVE WAS 0.104" DEEP

EXAMPLE FRAGMENTS FROM TEST QN0514A0



FIGURE 514-7

| | |
|---|---|
| TARGETS AA - FF | 4'x4'x8' CELOTEX PACKS |
| TARGETS A - O | 4'x6' WITNESS SHEETS |
| TARGETS 1,3 | 4'x12' DOUBLE STEEL WITNESS SHEETS. 6" SPACING |
| TARGETS 2,4 | 4'x6' SINGLE STEEL WITNESS SHEETS |




ARENA FOR
TEST QN0514A0



FIGURE 514-8

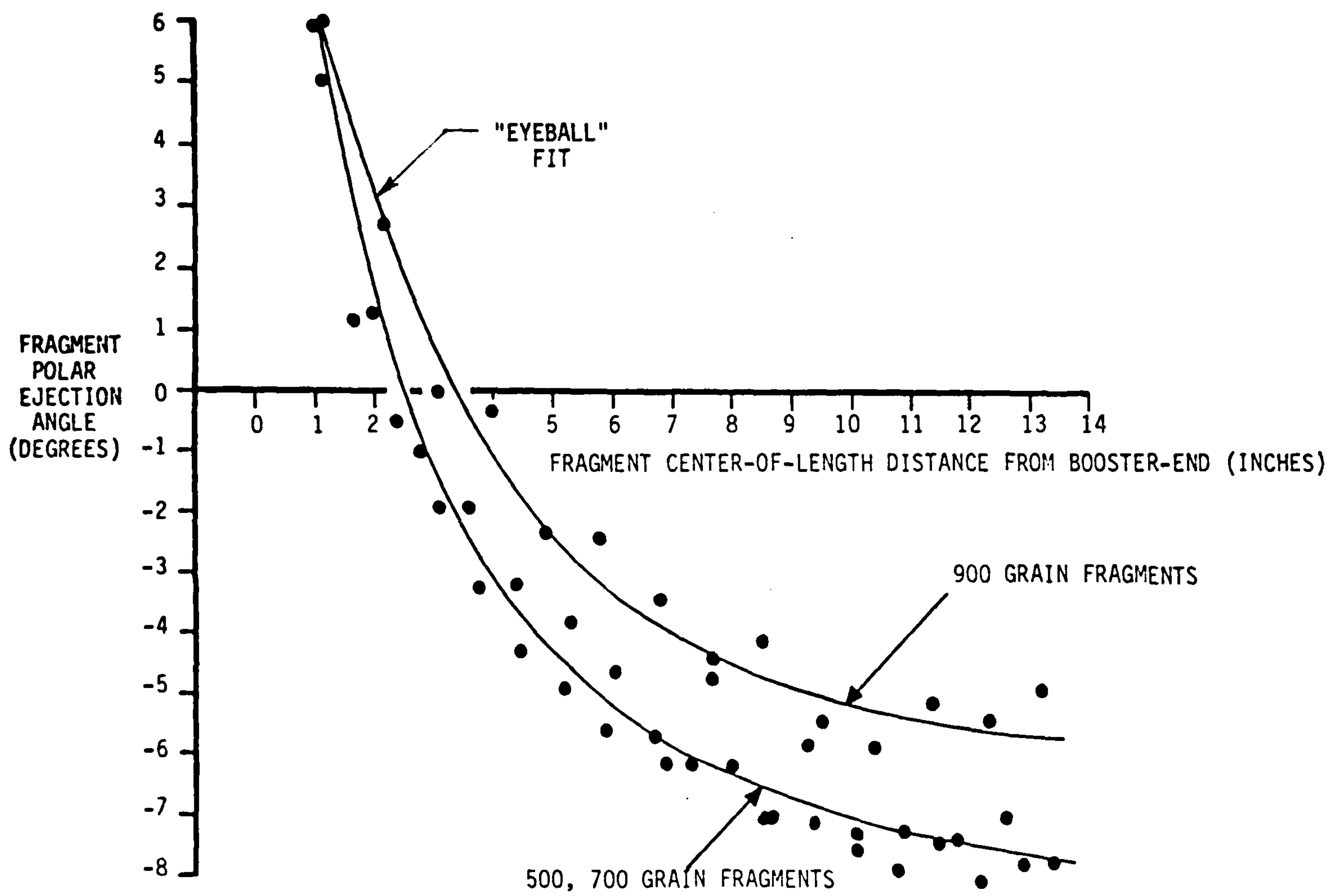
TEST QN0514A0

SUMMARY OF FRAGMENT POLAR EJECTION ANGLE AND VELOCITY RESULTS

| FRAGMENT ROW | FRAGMENT C.G. DISTANCE FROM BOOSTER END (IN) | POLAR EJECTION ANGLES 500-GR | 700-GR | 900-GR | POLAR ANGLE SUMMARY | AVERAGE VELOCITY (0-15') (ft/sec) |
|---|---|---|---|---|---|---|
| 1 | 1.0 | +5.9 | | | +5.9 | 4100 |
| 1 | 1.2 | | +5.0 | | +5.0 | |
| 1 | 1.2 | | | +6.0 | +6.0 | 4100 |
| 2 | 1.7 | +1.2 | | | +1.2 | 4800 |
| 2 | 2.0 | | +1.3 | | +1.3 | |
| 2 | 2.2 | | | +2.7 | +2.7 | 4700 |
| 3 | 2.4 | -0.5 | | | -0.5 | 4900 |
| 3 | 2.8 | | -1.0 | | -1.0 | |
| 3 | 3.1 | | | 0 | 0.0 | 5000 |
| 4 | 3.1 | -1.9 | | | -1.9 | 5100 |
| 4 | 3.6 | | -1.9 | | -1.9 | |
| 5 | 3.8 | -3.2 | | | -3.2 | 5400 |
| 4 | 4.0 | | | -0.3 | -0.3 | 5200 |
| 5 | 4.4 | | -3.2 | | -3.2 | |
| 6 | 4.5 | -4.3 | | | -4.3 | 5400 |
| 5 | 4.9 | | | -2.3 | -2.3 | 5200 |
| 7 | 5.2 | -4.9 | | | -4.9 | 5400 |
| 6 | 5.3 | | -3.8 | | -3.8 | |
| 6 | 5.8 | | | -2.4 | -2.4 | 5300 |
| 8 | 5.9 | -5.6 | | | -5.6 | 5400 |
| 7 | 6.1 | | -4.6 | | -4.6 | |
| 9 | 6.6 | -5.7 | | | -5.7 | 5400 |
| 7 | 6.8 | | | -3.4 | -3.4 | 5300 |
| 8 | 6.9 | | -6.1 | | -6.1 | |
| 10 | 7.3 | -6.1 | | | -6.1 | 5400 |
| 8 | 7.7 | | | -4.4 | -4.4 | 5500 |
| 9 | 7.7 | | -4.7 | | -4.7 | |
| 11 | 8.0 | -6.2 | | | -6.2 | 5400 |
| 9 | 8.5 | | | -4.1 | -4.1 | 5300 |
| 10 | 8.6 | | -7.0 | | -7.0 | |
| 12 | 8.7 | -7.0 | | | -7.0 | 5400 |
| 11 | 9.3 | | -5.8 | | -5.8 | |
| 13 | 9.4 | -7.1 | | | -7.1 | 5400 |
| 10 | 9.5 | | | -5.4 | -5.4 | 5500 |
| 12 | 10.1 | | -7.5 | | -7.5 | |
| 14 | 10.1 | -7.2 | | | -7.2 | 5400 |
| 11 | 10.4 | | | -5.8 | -5.8 | 5300 |
| 15 | 10.8 | -7.8 | | | -7.8 | 5400 |
| 13 | 10.9 | | -7.2 | | -7.2 | |
| 12 | 11.4 | | | -5.1 | -5.1 | 5500 |
| 16 | 11.5 | -7.4 | | | -7.4 | 5400 |
| 14 | 11.8 | | -7.3 | | -7.3 | |
| 17 | 12.2 | -8.0 | | | -8.0 | 5400 |
| 13 | 12.3 | | | -5.5 | -5.5 | 5300 |
| 15 | 12.6 | | -7.0 | | -7.0 | |
| 18 | 12.9 | -7.7 | | | -7.7 | 5400 |
| 14 | 13.2 | | | | -4.9 | |
| 16 | 13.4 | | -7.7 | | -7.7 | |



FIGURE 514-9




FRAGMENT POLAR EJECTION ANGLE AS A FUNCTION OF THE FRAGMENT CENTER-OF-LENGTH DISTANCE FROM THE BOOSTER END OF THE WARHEAD

TEST QN0514A0



FIGURE 514-10

TEST QN0514A0

500-GRAIN HEX HIBAL FRAGMENTS
VERTICAL MEASUREMENTS OF FRAGMENT HIT LOCATION (INCHES)
RELATIVE TO THE TOP OF THE WARHEAD

| FRAGMENT ROW | FRAGMENT COLUMN | | | | AVERAGE |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| 1 | +21.0 | | +12.0 | | +17.0 |
| 2 | | + 2.0 | | + 2.0 | + 2.0 |
| 3 | - 3.0 | | - 5.0 | | - 4.0 |
| 4 | | -10.0 | | - 8.0 | - 9.0 |
| 5 | -13.0 | | -14.0 | | -13.5 |
| 6 | | -18.0 | | -17.0 | -17.5 |
| 7 | -21.0 | | -19.0 | | -20.0 |
| 8 | | -24.0 | | -22.0 | -23.0 |
| 9 | -24.0 | | -24.0 | | -24.0 |
| 10 | | -26.0 | | -26.0 | -26.0 |
| 11 | -27.0 | | -27.0 | | -27.0 |
| 12 | | -31.0 | | -29.0 | -30.0 |
| 13 | -30.0 | | -32.0 | | -31.0 |
| 14 | | -34 | | -30.0 | -32.0 |
| 15 | -35.0 | | -34.0 | | -34.5 |
| 16 | | -35.0 | | -33.0 | -34.0 |
| 17 | -37.0 | | -36.0 | | -36.5 |
| 18 | | -37.0 | | -36.0 | -36.5 |



FIGURE 514- 11

TEST QN0514A0

700-GRAIN HEX HIBAL FRAGMENTS
VERTICAL MEASUREMENTS OF FRAGMENT HIT LOCATION (INCHES)
RELATIVE TO THE TOP OF THE WARHEAD

| FRAGMENT ROW | FRAGMENT COLUMN | | | AVERAGE |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| 1 | | +14.0 | | +14.0 |
| 2 | + 2.0 | | + 2.0 | + 2.0 |
| 3 | | - 6.0 | | - 6.0 |
| 4 | - 9.0 | | -10.0 | - 9.5 |
| 5 | | -14.0 | | -14.0 |
| 6 | -18.0 | | -16.0 | -17.0 |
| 7 | | -20.0 | | -20.0 |
| 8 | -24.0 | | -27.0 | -25.5 |
| 9 | | -22.0 | | -22.0 |
| 10 | -29.0 | | -31.0 | -30.0 |
| 11 | | -27.0 | | -27.0 |
| 12 | -33.0 | | | -33.0 |
| 13 | | -33.0 | | -33.0 |
| 14 | -34.0 | | | -34.0 |
| 15 | | -34.0 | | -34.0 |
| 16 | -37.0 | | | -37.0 |



FIGURE 514-12

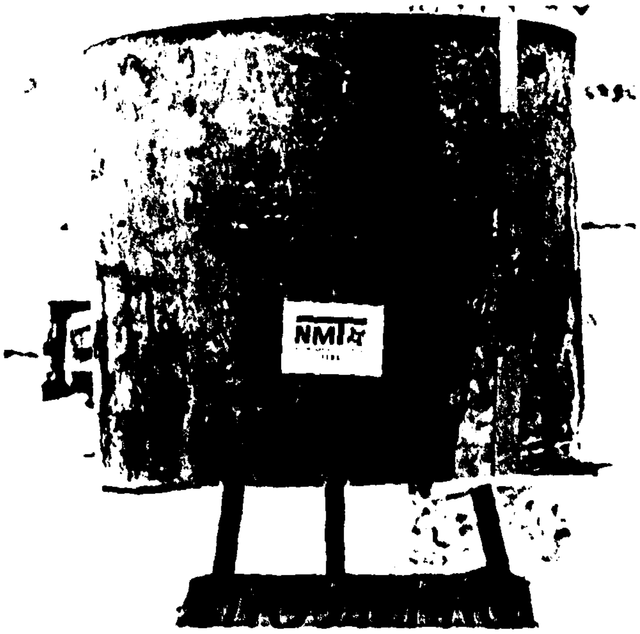
TEST QN0514A0

900-GRAIN HEX HIBAL FRAGMENTS
VERTICAL MEASUREMENTS OF FRAGMENT HIT LOCATION (INCHES)
RELATIVE TO THE TOP OF THE WARHEAD

| FRAGMENT ROW | FRAGMENT COLUMN | |
|---|---|---|
| | 1 | 2 |
| 1 | | +17.0 |
| 2 | + 6.0 | |
| 3 | | - 3.0 |
| 4 | - 5.0 | |
| 5 | | -12.0 |
| 6 | -13.0 | |
| 7 | | -17.0 |
| 8 | -21.0 | |
| 9 | | -21.0 |
| 10 | -26.0 | |
| 11 | | -28.0 |
| 12 | -27.0 | |



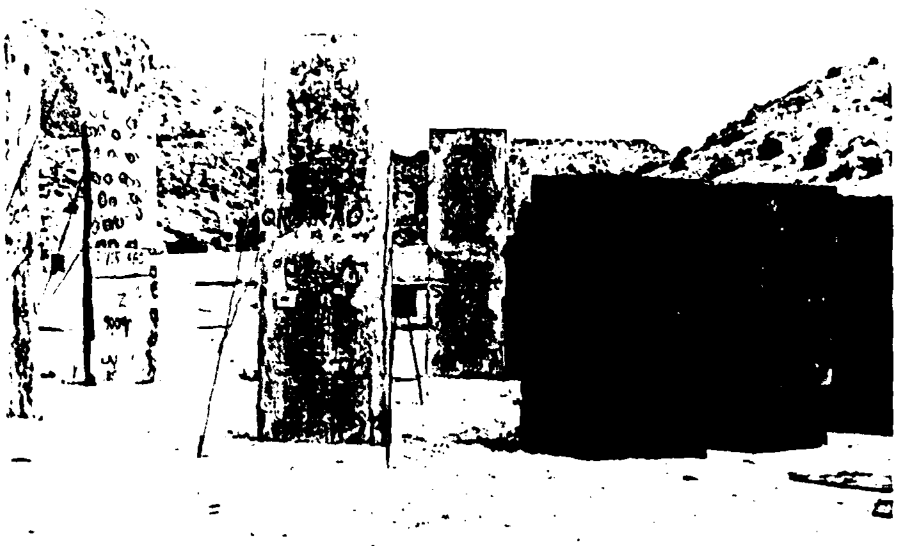
FIGURE 514- 13

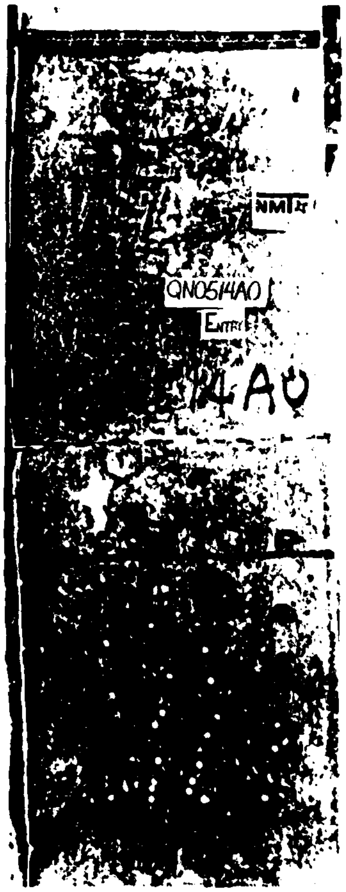

WARHEAD BEFORE AND AFTER SHROUD IS PLACED IN POSITION

TEST QN0514A0

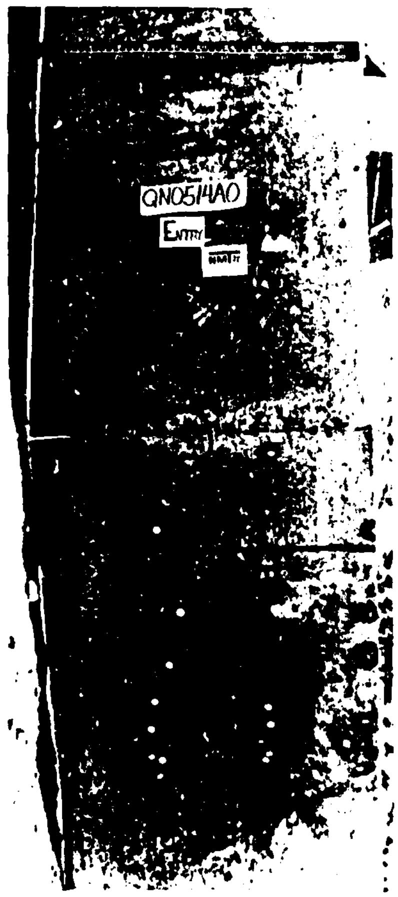
FIGURE 514-14



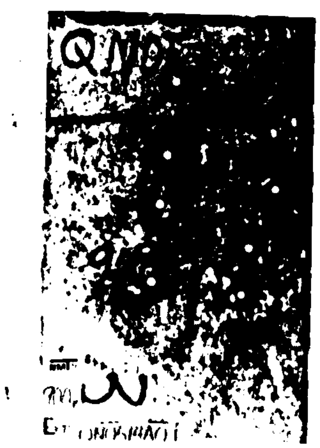
TEST ARENA FOR QN0514A0




500-grain FRAGMENT




700-grain FRAGMENT



900-grain FRAGMENT

FRAGMENT PATTERN WITNESS SHEETS FOR
500, 700, AND 900, GRAIN HEX HIBAL FRAGMENTS

TEST QN0514A0



FIGURE 514-16

## 2.2 SUMMARY OF WARHEAD TEST RESULTS

### 2.2.1 SUMMARY, PREFORMED-FRAGMENT WARHEADS

The comparison of predicted and measured fragment velocities and polar ejection-angles for each of the four warhead sizes are presented in tables 2.2.1 thru 2.2.4.

#### 2.2.1.1 VELOCITY

For the 8-inch diameter, 80-lb, and the 11.5-inch diameter, 135-lb warheads the measured values were close to the predicted values, and slightly lower than the predicted values for the 11.5-inch diameter, 200-lb warhead and the 19-inch diameter, 200-lb warhead. The fragment velocities from the 11.5-inch diameter, 200-lb warhead were still within the range of desired fragment velocities (5000-5500-ft/sec), but the velocities from the 19-inch diameter, 200-lb warhead were below this range.

#### 2.2.1.2 POLAR ANGLE

For the 8-inch diameter, 80-lb warhead the measured polar ejection-angles were very close to the predicted values. For the 11.5-inch diameter, 135-lb warhead, the measured ejection-angles were close to the predicted except for the two end-rows of fragments, which did not spread as much as predicted. For the 11.5-inch diameter, 200-lb warhead the fragment ejection-angles near the booster-end of the warhead were very close to predicted, but the fragments near the non-booster end did not spread as much as predicted. For the 19-inch diameter, 200-lb warhead, the three rows of fragments nearest the booster-end, and the row of fragments furthest from the booster-end did not spread as much as predicted. The remaining 10 rows of fragments in this warhead were close to the predicted values.

#### 2.2.1.3 FRAGMENT QUALITY

The preformed hex HIBAL fragments lost no fragment weight from either the detonation or from perforation of the shrouds or the recovery medium. Minor fragment deformation, resulting from the explosive sweep, occurred in each of the tests.

### 2.2.2 SUMMARY, FIREFORMED-FRAGMENT WARHEADS

For the 8-inch, 80-lb; the 11.5-inch, 135-lb; and the 11.5-inch, 200-lb fireformed-fragment warheads; the comparison of predicted and measured polar ejection-angles and velocities are presented in tables 2.2.5 thru 2.2.7. For the 19-inch diameter, 200-lb warhead, no table comparing actual vs predicted values was prepared because; (a) no useful polar angle data was acquired, and (b) the velocity bounds established from the data did not permit a row-by-row comparison to be made.

#### 2.2.2.1 VELOCITY

The fragment velocities for the 8-inch, 80-lb; 11.5-inch, 135-lb; and the 11.5-inch, 200-lb warheads, were close to the predicted values. For the 19-inch, 200-lb warhead, the highest fragment velocities were about five percent less than the predicted value* for this size warhead without shroud. The velocity bounds defined by the data from the 19-inch test strongly suggest that the velocity of the fireformed fragments will conform to the preformed-fragment-velocity characterization, for the same c.g. locations and shroud conditions.

#### 2.2.2.2 POLAR ANGLE

The measured polar ejection-angles for the 8-inch diameter, 80-lb warhead were close to the design values of polar ejection-angles. Improper lengthwise pairings of fragments occurred in the tests of the other three sizes of warheads, which altered the fragment polar ejection-angles. Thus the resulting fragment patterns were narrower than predicted, a natural result of the unwanted, lengthwise pairings of fragments. On the basis of comparative data from subsequent tests (QN0811A0 and QN0819A0) it appears to be safe to assume that the polar angle distribution for the fireformed fragments will be essentially the same as for preformed fragments having the same c.g. locations and end configurations.

#### 2.2.2.3 SUMMARY OF THE EFFECTS ON FRAGMENT QUALITY OF VARIATIONS IN OPPOSED-GROOVE DESIGNS

The data demonstrate that when the opposed grooves are designed properly, loss of fragment weight in fireforming can be limited to between ten and fifteen percent.

---

* (Using the Brown-Modified Gurney Equation, see footnote in Appendix III.)

## A. Included Angle

The included angle of the grooves was maintained at 37 degrees for all the fireformed-fragment-warhead tests and, thus, the effects of variations in groove angle on resulting fragment quality cannot be ascertained from the warhead test data. (NOTE: The mat firing data (Appendix I) indicated that relatively wide angle grooves (90°-120°) require the presence of a relatively dense inert filler material in the outside grooves to achieve proper fragment fireforming.)

## B. Longitudinal Grooves

The test results indicate that fragment quality is primarily a function of the metal remaining between the apexes of the opposed grooves. Best results were obtained when the metal remaining between inside and outside grooves was a maximum of 0.220-inch to 0.240-inch. When the metal remaining between the apexes of the grooves exceeds this value, undesirable results such as partial fragments or fragment "borrowing" from its neighbor occur. Data from Test QN0514A0 show that the resulting fragment quality is not sensitive to the ratio of the depths of the inside and outside grooves as long as the remaining metal value is 0.220 to 0.240-inch; The loss of metal removed from the case by the grooving process is minimized when the inside and outside grooves are of equal depth. Spacing between longitudinal grooves was varied from 0.625-inch to 1.188-inch with no apparent effect on fragment quality.

## C. Circumferential Grooves

The metal remaining between the apexes of the inside and outside grooves must not exceed "threshold" limits, to prevent fragment lengthwise pairing. For the 8"-diameter, 80-lb warhead the opposed groove design was adequate to achieve proper fragment breakout, (i.e. with no lengthwise pairings). For the other three warhead sizes, the depths of the opposed grooves were not adequate (in that too much metal remained between the apexes of the grooves), and lengthwise pairings of fragments resulted on the non-booster-end-half of the warhead. It is estimated that proper lengthwise breakout will be achieved when the metal remaining between the apexes of the grooves is 0.100-inch.

When the inside groove depth exceeds 0.120-inch, the inside non-booster-end edge of the fragment is broken off by the detonation.

### 2.2.2.4 SUMMARY OF THE DESIGN EVOLUTION FOR THE FIREFORMED FRAGMENT, OPPOSED GROOVE, WARHEADS

The results of the fragment mat tests were used to design the first fireformed warhead test, QN0225A0, which was 8-inch diameter, 0.488-inch case thickness. Excellent fireforming results were achieved in this first test.

The second and third tests, QN0311A0 and QN0328A0 represented a change in both warhead diameter and warhead case thickness. There were several design approaches for opposed grooving which were possible. Proper fireforming of fragments could be dependent on:

1. The depths of the inside and outside grooves (or sum of the depths).

2. The ratio of the depths of the grooves to the case thickness.

3. The metal thickness remaining between the apexes of the opposed grooved.

Design approaches 1 and 2 were pursued in tests QN0311A0 and QN0328A0. The results of these tests demonstrated that the design approaches were not the correct ones to follow.

In test QN0409A0, the design approach was changed to provide for the metal thickness remaining between opposed grooves to bracket those values which were successful in the first test QN0225A0.

Excellent fragments were recovered in test QN0409A0; however, the Celotex recovery medium contributed to breaking the fragments at the circumferential grooves (a fact which was not recognized until the results of the following test were obtained).

Test QN0429A0 served to provide upper bounds on the metal thickness remaining between longitudinal grooves for proper fireforming, and demonstrated that too much metal remained between the opposed circumferential grooves.

In test QN0514A0, circumferential groove depths were significantly increased so as to reduce the metal remaining between opposed grooves. However, this increase in groove depth proved to be insufficient.

Subsequent tests (QN0811A0 and QN0819A0) of 60-degree sectors of the 19-inch annular warhead, using the groove depths and groove spacings associated with the follow-on warhead designs contained in this report, have yielded fragments that broke up as desired, had good shape characteristics, weighed within 2% of their design weight and had a polar ejection pattern that was essentially identical to the pattern measured for the preformed fragments fired from this 19-inch warhead in test No. QN0409A0.

TABLE 2.2.1

COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND POLAR EJECTION ANGLES FOR THE 8-INCH DIAMETER, 80-LB PREFORMED HEX HIBAL WARHEAD, FOR 700-GRAIN HEX HIBALS

| FRAGMENT ROW | POLAR EJECTION ANGLE (degrees) PREDICTED | POLAR EJECTION ANGLE (degrees) MEASURED | FRAGMENT VELOCITY (ft/sec) PREDICTED | FRAGMENT VELOCITY (ft/sec) MEASURED |
|---|---|---|---|---|
| 1* | + 4.7 | + 4.7 | 4100 | 4300 |
| 2 | + 1.2 | + 1.2 | 4300 | 4800 |
| 3 | - 0.7 | - 0.7 | 4600 | 5000 |
| 4 | - 1.8 | - 1.8 | 4800 | 5200 |
| 5 | - 2.7 | - 2.7 | 5000 | 5400 |
| 6 | - 3.2 | - 3.2 | 5100 | 5400 |
| 7 | - 3.6 | - 3.6 | 5200 | 5500 |
| 8 | - 3.9 | - 3.9 | 5300 | 5500 |
| 9 | - 4.2 | - 4.2 | 5400 | 5600 |
| 10 | - 4.3 | - 4.3 | 5500 | 5700 |
| 11 | - 4.7 | - 4.7 | 5500 | 5600 |
| 12 | - 5.4 | - 5.4 | 5500 | 5600 |
| 13 | - 5.5 | - 5.5 | 5500 | 5600 |
| 14 | - 5.7 | - 5.7 | 5400 | 5500 |
| 15 | - 5.8 | - 5.8 | 5300 | 5600 |
| 16 | - 6.1 | - 6.1 | 5000 | 5400 |

* Row of fragments closest to booster end of warhead

## TABLE 2.2.2

### COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND POLAR EJECTION ANGLES FOR THE 11.5-INCH DIAMETER, 135-LB PREFORMED HEX HIBAL WARHEAD, FOR 700-GRAIN HEX HIBALS

| FRAGMENT ROW | POLAR EJECTION ANGLE (degrees) | | FRAGMENT VELOCITY (ft/sec) | |
|---|---|---|---|---|
| | PREDICTED | MEASURED | PREDICTED | MEASURED |
| 1* | +10.0 | + 5.0 | 4450 | 4100 |
| 2 | + 3.0 | + 1.3 | 4900 | 4750 |
| 3 | 0 | - 1.0 | 5000 | 4950 |
| 4 | - 1.3 | - 1.9 | 5350 | 5200 |
| 5 | - 1.9 | - 3.2 | 5550 | 5300 |
| 6 | - 2.6 | - 3.8 | 5600 | 5350 |
| 7 | - 4.8 | - 4.6 | 5650 | 5400 |
| 8 | - 4.9 | - 6.1 | 5650 | 5400 |
| 9 | - 5.8 | - 4.7 | 5700 | 5400 |
| 10 | - 5.8 | - 7.0 | 5700 | 5400 |
| 11 | - 6.2 | - 5.8 | 5700 | 5400 |
| 12 | - 6.3 | - 7.5 | 5700 | 5400 |
| 13 | - 6.6 | - 7.2 | 5650 | 5400 |
| 14 | - 6.8 | - 7.3 | 5550 | 5400 |
| 15 | - 7.8 | - 7.0 | 5350 | 5400 |
| 16 | -11.0 | - 7.7 | 5000 | 5400 |

* Row of fragments closest to booster end of warhead

TABLE 2.2.3

COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND EJECTION ANGLES FOR THE 11.5-INCH DIAMETER, 200-LB PREFORMED HEX HIBAL WARHEAD, FOR 700-GRAIN HEX HIBALS

| FRAGMENT | POLAR EJECTION ANGLE (degrees) | | FRAGMENT VELOCITY (ft/sec) | |
|---|---|---|---|---|
| ROW | PREDICTED | MEASURED | PREDICTED | MEASURED |
| 1* | +10.0 | + 9.5 | 4300 | 4100 |
| 2 | + 5.0 | + 5.0 | 4600 | 4200 |
| 3 | 0 | + 2.5 | 5200 | 4300 |
| 4 | - 1.0 | + 1.0 | 5300 | 4500 |
| 5 | - 2.0 | - 0.3 | 5400 | 4850 |
| 6 | - 3.0 | - 1.4 | 5500 | 4500 |
| 7 | - 3.5 | - 2.0 | 5600 | 5000 |
| 8 | - 4.0 | - 2.3 | 5700 | 5000 |
| 9 | - 4.5 | - 2.2 | 5700 | 5100 |
| 10 | - 5.0 | - 3.2 | 5700 | 4850 |
| 11 | - 5.8 | - 3.1 | 5800 | 5100 |
| 12 | - 6.0 | - 3.9 | 5800 | 5100 |
| 13 | - 6.2 | - 3.8 | 5800 | 5300 |
| 14 | - 6.3 | - 4.5 | 5900 | 5100 |
| 15 | - 6.6 | - 4.3 | 5900 | 5300 |
| 16 | - 6.8 | - 5.0 | 5900 | 5450 |
| 17 | - 7.0 | - 4.6 | 5900 | 5450 |
| 18 | - 7.0 | - 5.0 | 5800 | 5450 |
| 19 | - 7.0 | - 4.4 | 5800 | 5450 |
| 20 | - 7.5 | - 5.0 | 5600 | 5450 |
| 21 | - 8.0 | - 4.5 | 5500 | 5300 |
| 22 | - 9.0 | - 4.8 | 5400 | 5300 |
| 23 | -11.0 | - 4.9 | 5200 | 5000 |

* Row of fragments closest of booster end of warhead

TABLE 2.2.4

COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND POLAR EJECTION ANGLES FOR THE 19-INCH DIAMETER, 200-LB PREFORMED HEX HIBAL WARHEAD, FOR 700-GRAIN HEX HIBALS

| FRAGMENT ROW | POLAR EJECTION ANGLE (degrees) | | FRAGMENT VELOCITY (ft/sec) | |
|---|---|---|---|---|
| | PREDICTED | MEASURED | PREDICTED | MEASURED |
| 1* | +25.0 | +15.0 | 4600 | 3500 |
| 2 | + 8.8 | + 4.9 | 4850 | 3900 |
| 3 | + 5.0 | + 0.8 | 5050 | 4300 |
| 4 | 0 | - 0.7 | 5250 | 4500 |
| 5 | - 1.5 | - 2.6 | 5400 | 4600 |
| 6 | - 2.5 | - 3.5 | 5500 | 4700 |
| 7 | - 3.0 | - 4.6 | 5600 | 4800 |
| 8 | - 4.0 | - 4.2 | 5600 | 4900 |
| 9 | - 4.5 | - 5.5 | 5600 | 4900 |
| 10 | - 5.0 | - 5.3 | 5600 | 4900 |
| 11 | - 5.5 | - 6.1 | 5500 | 4900 |
| 12 | - 5.5 | - 6.0 | 5400 | 4800 |
| 13 | - 8.0 | - 7.6 | 5200 | 4600 |
| 14 | -15.0 | -10.3 | 5000 | 4500 |

*Row of fragments closest to booster end of warhead

TABLE 2.2.5

COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND POLAR EJECTION ANGLES FOR THE 8-INCH DIAMETER, 80-LB FIREFORMED HIBAL WARHEAD

| FRAGMENT ROW | POLAR EJECTION ANGLE (degrees) | | FRAGMENT VELOCITY (ft/sec) | |
|---|---|---|---|---|
| | PREDICTED | MEASURED | PREDICTED | MEASURED |
| 1* | + 5.1 | + 8.5 | 4100 | 4500 |
| 2 | - 1.0 | + 4.1 | 4300 | 4300 |
| 3 | - 1.3 | - 1.0 | 4600 | 4800 |
| 4 | - 1.9 | - 1.9 | 4800 | 5300 |
| 5 | - 2.6 | - 3.6 | 5000 | 5300 |
| 6 | - 4.8 | - 4.2 | 5100 | 5300 |
| 7 | - 4.9 | - 5.0 | 5200 | 5300 |
| 8 | - 5.8 | - 5.6 | 5300 | 5300 |
| 9 | - 5.8 | - 5.6 | 5400 | 5500 |
| 10 | - 6.2 | - 5.8 | 5500 | 5500 |
| 11 | - 6.3 | - 6.3 | 5500 | 5500 |
| 12 | - 6.6 | - 6.7 | 5500 | 5500 |
| 13 | - 6.8 | - 6.3 | 5400 | 5300 |
| 14 | - 7.2 | - 6.2 | 5300 | 5300 |
| 15 | - 7.8 | - 5.6 | 5000 | 5300 |

* Row of fragments closest to booster end of warhead.

## TABLE 2.2.6

## COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND POLAR EJECTION ANGLES FOR THE 11.5-INCH O.D., 135-LB FIREFORMED HIBAL WARHEAD

| FRAGMENT | POLAR EJECTION ANGLE (degrees) | | FRAGMENT VELOCITY (ft/sec) | |
|---|---|---|---|---|
| ROW | PREDICTED | MEASURED* | PREDICTED | MEASURED |
| 1+ | +20.0 | + 7.6 | 4450 | 4800 |
| 2 | - 1.0 | - 1.0 | 5150 | 5200 |
| 3 | - 1.3 | + 3.3 | 5350 | 5500 |
| 4 | - 1.9 | - 0.4 | 5550 | 5500 |
| 5 | - 2.6 | - 2.5 | 5600 | 5500 |
| 6 | - 4.8 | | 5650 | 5500 |
| 7 | - 4.9 | | 5650 | 5500 |
| 8 | - 5.8 | | 5700 | 5500 |
| 9 | - 5.8 | | 5700 | 5500 |
| 10 | - 6.2 | | 5700 | 5500 |
| 11 | - 6.3 | | 5700 | 5500 |
| 12 | - 6.6 | | 5650 | 5500 |
| 13 | - 6.8 | | 5550 | 5500 |
| 14 | - 7.8 | | 5350 | 5200 |
| 15 | -11.0 | - 7.1 | 5000 | 5200 |

+ Row of fragments closest to the booster end of warhead.

* Fragment lengthwise pairs made it impossible to provide specific values for fragment rows 3 through 14. All hits fell between -2.5° and -7.1°, however.

TABLE 2.2.7

COMPARISON OF PREDICTED AND MEASURED FRAGMENT VELOCITIES AND POLAR EJECTION ANGLES FOR THE 11.5-INCH DIAMETER,

| FRAGMENT ROW | POLAR EJECTION ANGLE (degrees) PREDICTED | POLAR EJECTION ANGLE (degrees) MEASURED* | FRAGMENT VELOCITY (ft/sec) PREDICTED | FRAGMENT VELOCITY (ft/sec) MEASURED |
|---|---|---|---|---|
| 1+ | + 7.0 | + 9.5 | 4600 | 4500 |
| 2 | - 1.0 | + 4.5 | 5200 | 4700 |
| 3 | - 1.3 | + 1.9 | 5400 | 4800 |
| 4 | - 1.9 | - 0.5 | 5500 | 5000-5300 |
| 5 | - 2.6 | - 4.0 | 5600 | 5000-5300 |
| 6 | - 4.8 | | 5700 | 5000-5300 |
| 7 | - 4.9 | | 5700 | 5200-5700 |
| 8 | - 5.8 | | 5700 | 5200-5700 |
| 9 | - 5.8 | | 5800 | 5200-5700 |
| 10 | - 6.2 | | 5800 | 5200-5700 |
| 11 | - 6.3 | | 5800 | 5200-5700 |
| 12 | - 6.6 | | 5900 | 5200-5700 |
| 13 | - 6.8 | | 5900 | 5200-5700 |
| 14 | - 7.0 | | 5800 | 5200-5700 |
| 15 | - 7.5 | | 5800 | 5200-5700 |
| 16 | - 8.0 | | 5600 | 5200-5700 |
| 17 | - 8.5 | | 5500 | 5200-5700 |
| 18 | - 9.0 | | 5400 | 5200-5700 |
| 19 | -11.0 | - 7.5 | 5000 | 5200-5700 |

+ Row of fragments closest to the booster end of warhead.

* Because some fragment lengthwise pairing and some breakup occurred, specific values of polar ejection angle cannot be assigned fragment rows 6 through 19. All hits occurred between -4.0° and -7.5°, however.

## 3.0 CONCLUSIONS

In general, the Preliminary Warhead tests have demonstrated that the original design criteria can be satisfied by both preformed and fireformed warhead designs.

## 3.1 CONCERNING FRAGMENT EJECTION CHARACTERISTICS

### 3.1.1 FRAGMENT VELOCITY (Fireformed vs Preformed)

For equal charge-to-metal ratios and equal shroud conditions there is no significant difference between the fragment velocities achieved with a fireformed fragment case and the fragment velocities achieved with a preformed fragment case.

Ejection velocities can be accurately predicted, as described in Section 3.4.

### 3.1.2 POLAR ANGLE

Polar ejection angles can be accurately predicted for both the fireformed and preformed fragments with the methodologies presented in Section 3.4 and in Appendix III, with the exception of the row of fragments nearest each end of the warhead. The end row of fragments is very sensitive to the end configuration, and changes in the polar ejection angle as a function of the end configuration cannot, at this time, be predicted with confidence.

## 3.2 CONCERNING THE OPPOSED GROOVE FIREFORMING TECHNIQUE FOR GENERATING HIBAL FRAGMENTS

The results summarized in Section 2.2.2 demonstrate the feasibility of generating fireformed fragments with the shape and toughness needed to qualify as HIBAL-type fragments, from all four warhead sizes.

## 3.3. WARHEAD MODELS FORMULATED FOR USE IN END GAME ANALYSES

The warhead models which were formulated for use in the end game analysis during the next phase of HIBAL effort are presented in Tables 3.3.1 through 3.3.8. A high level of confidence is placed in the ability of the warhead designs described in Tables 3.3.9 and 3.3.10 to generate fragments having the characteristics given in Tables 3.3.1 through 3.3.8.

## 3.4 GUIDELINES FOR THE DESIGN OF FUTURE WARHEADS

### 3.4.1 WARHEAD CHARACTERIZATION

Curves presented in Figures 3.4.1 through 3.4.4 can be used to predict fragment ejection-angles and velocities for each of the four warhead sizes presented herein, and are deemed adequate for predicting either preformed or fireformed fragments.

It should be noted that changes in the design of the ends of the warhead can significantly alter the fragment ejection characterization near the ends.

### 3.4.2 OPPOSED-GROOVE DESIGN

When designing warheads utilizing the opposed groove technique, caution should be exercised when designing fragment sizes. The metal weight removed in the both the grooving process and fireforming process must be planned for.

### 3.4.3 Structural Strength

Because of the deep grooves required to produce good breakup of the warhead case, there is no structural advantage of the solid-case, opposed-groove design, over a preformed fragment design having inner and outer stress skins.

## 4.0 EVALUATION OF UNCERTAINTIES

## 4.1 FOR BOTH PREFORMED AND FIREFORMED FRAGMENT WARHEADS

### 4.1.1 END CONFIGURATION

Missile attachment structural details are likely to have a significant effect on the velocity and polar ejection angles of the fragments located closest to the ends of the warhead.

### 4.1.2 SHROUD DETAILS

The missile shroud used in any given application may differ from the simulations used in these tests and this may significantly alter the effect on fragment velocity, ejection angles, shape and weight.

## 4.2 PREFORMED FRAGMENT WARHEADS

### 4.2.1 SKIN THICKNESS

The skin thickness (both inside and outside) necessary to meet environmental and/or structural requirements in any given application may differ significantly from the thickness used in these tests. The use of different skin thicknesses may significantly affect fragment polar ejection angle, velocity, shape and weight.

## 4.3 FIREFORMED FRAGMENT WARHEADS

### 4.3.1 FRAGMENT CASE ALLOY

Opposed groove designs may change, in terms of the metal thickness between the apexes of the opposed grooves, for differing alloys. No problem is foreseen in developing an opposed groove design which will properly fireform fragments for most alloy steels, or mild steels.

# TABLE 3.3.1

## WARHEAD CHARACTERIZATIONS

PREDICTED FOR 8-INCH DIAMETER x 80-LB WARHEADS
CONTAINING PREFORMED HEX HIBAL FRAGMENTS

(BASED ON DATA OBTAINED FROM TEST NO. QN0319A0)

| | FRAGMENT DETAILS | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 450 | 352 | 266 |
| WIDTH ACROSS FLATS (inch) | 7/8 | 1 | 1-1/8 |
| THICKNESS (inch) | 0.42 | 0.42 | 0.42 |
| | | | |

| | FRAGMENT EJECTION CHARACTERISTICS (1) | | | | | |
|---|---|---|---|---|---|---|
| ROW NO. | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| A (2) (3) | | | | | | |
| 1 | +4.5 | 4300 | +4.0 | 4300 | +3.5 | 4400 |
| 2 | +1.0 | 4700 | +1.0 | 4700 | +0.5 | 4800 |
| 3 | 0.0 | 5000 | -1.0 | 5000 | -1.5 | 5100 |
| 4 | -1.5 | 5200 | -2.0 | 5300 | -2.5 | 5300 |
| 5 | -2.5 | 5300 | -3.0 | 5400 | -3.5 | 5500 |
| 6 | -3.0 | 5400 | -3.5 | 5500 | -4.0 | 5600 |
| 7 | -3.5 | 5500 | -4.0 | 5600 | -4.5 | 5600 |
| 8 | -4.0 | 5600 | -4.5 | 5600 | -5.0 | 5700 |
| 9 | -4.0 | 5600 | -5.0 | 5700 | -5.0 | 5700 |
| 10 | -4.5 | 5700 | -5.0 | 5700 | -5.5 | 5700 |
| 11 | -5.0 | 5700 | -5.5 | 5700 | -5.5 | 5700 |
| 12 | -5.0 | 5700 | -5.5 | 5700 | -6.0 | 5700 |
| 13 | -5.5 | 5700 | -5.5 | 5700 | -6.0 | 5600 |
| 14 | -5.5 | 5700 | -6.0 | 5600 | -6.0 | 5500 |
| 15 | -6.0 | 5700 | -6.0 | 5600 | | |
| 16 | -6.0 | 5600 | -6.0 | 5500 | | |
| 17 | -6.0 | 5600 | | | | |
| 18 | -6.0 | 5500 | | | | |
| B (2) | | | | | | |

**NOTES:**

(1) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.

(2) A and B are end-ring rows.

(3) Booster end.

TABLE 3.3.2

WARHEAD CHARACTERIZATIONS

PREDICTED FOR 8-INCH DIAMETER x 80-LB WARHEADS
CONTAINING FIREFORMED HIBAL FRAGMENTS

(BASED ON DATA OBTAINED IN TEST NO. QN0225A0)

| | FRAGMENT DETAILS (1) | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 504 | 375 | 286 |
| CIRCUMFERENTIAL WIDTH: | | | |
| INSIDE | 0.799 | 0.895 | 1.017 |
| OUTSIDE | 0.898 | 1.005 | 1.142 |
| LONGITUDINAL WIDTH: | 0.833 | 1.0 | 1.154 |
| THICKNESS | 0.4375 | 0.4375 | 0.4375 |

| FRAGMENT ROW | FRAGMENT EJECTION CHARACTERISTICS (2) | | | | | |
|---|---|---|---|---|---|---|
| | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| 1 (3) | +14.0 | 4300 | +13.5 | 4400 | +13.0 | 4400 |
| 2 | + 8.0 | 4600 | + 6.0 | 4600 | + 5.0 | 4700 |
| 3 | + 3.0 | 4800 | + 1.5 | 4800 | 0.0 | 4900 |
| 4 | + 0.0 | 4900 | - 1.0 | 5000 | - 2.0 | 5100 |
| 5 | - 1.5 | 5100 | - 3.0 | 5200 | - 4.0 | 5200 |
| 6 | - 3.0 | 5200 | - 4.0 | 5300 | - 5.0 | 5300 |
| 7 | - 4.0 | 5300 | - 5.0 | 5400 | - 5.5 | 5400 |
| 8 | - 5.0 | 5400 | - 5.5 | 5400 | - 6.0 | 5500 |
| 9 | - 5.5 | 5400 | - 6.0 | 5500 | - 6.5 | 5500 |
| 10 | - 6.0 | 5400 | - 6.5 | 5500 | - 6.5 | 5500 |
| 11 | - 6.0 | 5500 | - 6.5 | 5500 | - 6.5 | 5400 |
| 12 | - 6.5 | 5500 | - 6.5 | 5400 | - 6.0 | 5400 |
| 13 | - 6.5 | 5500 | - 6.5 | 5400 | - 5.5 | 5300 |
| 14 | - 6.5 | 5500 | - 6.0 | 5300 | | |
| 15 | - 6.5 | 5400 | - 5.5 | 5300 | | |
| 16 | - 6.5 | 5400 | | | | |
| 17 | - 6.0 | 5300 | | | | |
| 18 | - 5.5 | 5300 | | | | |

**NOTES:**

(1) All linear dimensions are in inches.
(2) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(3) Booster end.

# TABLE 3.3.3

## WARHEAD CHARACTERIZATIONS

PREDICTED FOR 11.5-INCH DIAMETER x 135-LB WARHEADS
CONTAINING PREFORMED HEX HIBAL FRAGMENTS

(BASED ON DATA OBTAINED IN TEST NO. QN0514A0)

| | FRAGMENT DETAILS | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 720 | 560 | 403 |
| WIDTH ACROSS FLATS (inch) | 13/16 | 15/16 | 1-1/16 |
| THICKNESS (inch) | 0.485 | 0.485 | 0.485 |
| | | | |

| | FRAGMENT EJECTION CHARACTERISTICS (1) | | | | | |
|---|---|---|---|---|---|---|
| ROW NO. | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| A (2) (3) | | | | | | |
| 1 | +6.0 | 4100 | +5.0 | 4100 | +5.5 | 4150 |
| 2 | +1.0 | 4800 | +1.5 | 4750 | +2.0 | 4600 |
| 3 | -0.5 | 4900 | -1.0 | 4950 | 0.0 | 4900 |
| 4 | -2.0 | 5100 | -2.0 | 5200 | -1.0 | 5150 |
| 5 | -3.0 | 5400 | -3.5 | 5300 | -2.0 | 5300 |
| 6 | -4.0 | 5400 | -4.0 | 5350 | -3.0 | 5400 |
| 7 | -5.0 | 5400 | -5.0 | 5400 | -3.5 | 5450 |
| 8 | -5.5 | 5400 | -5.5 | 5400 | -4.0 | 5500 |
| 9 | -6.0 | 5400 | -6.0 | 5400 | -4.5 | 5500 |
| 10 | -6.0 | 5400 | -6.5 | 5400 | -5.0 | 5500 |
| 11 | -6.5 | 5400 | -7.0 | 5400 | -5.0 | 5450 |
| 12 | -7.0 | 5400 | -7.0 | 5400 | -5.5 | 5400 |
| 13 | -7.0 | 5400 | -7.0 | 5400 | -6.0 | 5350 |
| 14 | -7.5 | 5400 | -7.5 | 5400 | | |
| 15 | -7.5 | 5400 | -7.5 | 5400 | | |
| 16 | -8.0 | 5400 | -8.0 | 5400 | | |
| 17 | -8.0 | 5400 | | | | |
| 18 | -8.0 | 5400 | | | | |
| B (2) | | | | | | |

**NOTES:**

(1) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(2) A and B are end-ring rows.
(3) Booster end.

## TABLE 3.3.4

WARHEAD CHARACTERIZATIONS (4)

PREDICTED FOR 11.5-INCH DIAMETER x 135-LB WARHEADS
CONTAINING FIREFORMED HIBAL FRAGMENTS

(BASED ON DATA OBTAINED IN TEST NO. QN0514A0)

| FRAG. WT. | FRAGMENT DETAILS (1) 500-grain | 700-grain | 900-grain |
|---|---|---|---|
| TOTAL NO. | 731 | 555 | 429 |
| CIRCUMFERENTIAL WIDTH: INSIDE | 0.767 | 0.892 | 1.000 |
| CIRCUMFERENTIAL WIDTH: OUTSIDE | 0.840 | 0.976 | 1.095 |
| LONGITUDINAL WIDTH: | 0.824 | 0.933 | 1.077 |
| THICKNESS | 0.500 | 0.500 | 0.500 |

| FRAGMENT ROW | FRAGMENT EJECTION CHARACTERISTICS (2) POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
|---|---|---|---|---|---|---|
| 1 (3) | +4.5 | 4100 | +4.0 | 4200 | +4.0 | 4200 |
| 2 | +2.5 | 4500 | +2.0 | 4550 | +1.0 | 4600 |
| 3 | 0.0 | 4700 | -0.5 | 4800 | -1.0 | 4900 |
| 4 | -1.5 | 4900 | -2.0 | 5000 | -2.5 | 5100 |
| 5 | -2.5 | 5100 | -3.0 | 5200 | -3.5 | 5300 |
| 6 | -3.5 | 5200 | -4.0 | 5300 | -4.5 | 5400 |
| 7 | -4.0 | 5300 | -4.5 | 5400 | -5.0 | 5450 |
| 8 | -4.5 | 5400 | -5.0 | 5450 | -5.5 | 5500 |
| 9 | -5.0 | 5450 | -5.5 | 5500 | -6.0 | 5500 |
| 10 | -5.5 | 5500 | -6.0 | 5500 | -6.5 | 5500 |
| 11 | -6.0 | 5500 | -6.0 | 5500 | -6.5 | 5400 |
| 12 | -6.0 | 5500 | -6.5 | 5500 | -7.0 | 5400 |
| 13 | -6.5 | 5500 | -7.0 | 5400 | -7.0 | 5350 |
| 14 | -6.5 | 5450 | -7.0 | 5400 | | |
| 15 | -7.0 | 5400 | -7.0 | 5350 | | |
| 16 | -7.0 | 5400 | | | | |
| 17 | -7.0 | 5300 | | | | |

NOTES:

(1) All linear dimensions are in inches.

(2) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.

(3) Booster end.

(4) The characterizations shown on this page reflect the data from the relevant tests reported herein, but are not to be used for the second phase HIBAL end-game analysis. See Note 4 on page 26A.

# TABLE 3.3.4A

## WARHEAD CHARACTERIZATIONS
## PREDICTED FOR 11.5-INCH DIAMETER x 135-LB WARHEADS
## CONTAINING FIREFORMED HIBAL FRAGMENTS
## (BASED ON DATA OBTAINED IN TEST NO. QN0926A0) (4)

| | FRAGMENT DETAILS (1) | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 731 | 555 | 429 |
| CIRCUMFERENTIAL WIDTH: | | | |
| INSIDE | 0.767 | 0.892 | 1.000 |
| OUTSIDE | 0.849 | 0.976 | 1.095 |
| LONGITUDINAL WIDTH: | 0.824 | 0.933 | 1.077 |
| THICKNESS | 0.500 | 0.500 | 0.500 |

| | FRAGMENT EJECTION CHARACTERISTICS (2) | | | | | |
|---|---|---|---|---|---|---|
| FRAGMENT ROW | POLAR ANGLE (degrees) | VELOCITY AVG. 0-15' (ft/sec) | POLAR ANGLE (degrees) | VELOCITY AVG. 0-15' (ft/sec) | POLAR ANGLE (degrees) | VELOCITY AVG. 0-15' (ft/sec) |
| 1 (3) | +22 | 3100 | +21 | [illegible] | +20 | [illegible] |
| 2 | + 7 | 4100 | + 6 | 4200 | + 4 | [illegible] |
| 3 | + 2 | 4500 | + 1 | 4600 | 0 | [illegible] |
| 4 | 0 | 4800 | - 1 | 4900 | - 2 | [illegible] |
| 5 | - 2 | 5000 | - 2 | 5100 | - 3 | [illegible] |
| 6 | - 3 | 5100 | - 3 | 5200 | - 4 | 5300 |
| 7 | - 3 | 5200 | - 4 | 5300 | - 4 | 5300 |
| 8 | - 4 | 5300 | - 4 | 5300 | - 5 | 5400 |
| 9 | - 4 | 5300 | - 5 | 5400 | - 5 | 5400 |
| 10 | - 5 | 5400 | - 5 | 5400 | - 6 | 5400 |
| 11 | - 5 | 5400 | - 5 | 5400 | - 6 | 5300 |
| 12 | - 5 | 5400 | - 6 | 5400 | - 7 | 5200 |
| 13 | - 5 | 5400 | - 6 | 5300 | - 9 | 4900 |
| 14 | - 6 | 5400 | - 7 | 5100 | | |
| 15 | - 7 | 5300 | -10 | 4900 | | |
| 16 | - 7 | 5100 | | | | |
| 17 | -10 | 4900 | | | | |

NOTES:

(1) All linear dimensions are in inches.
(2) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(3) Booster end.
(4) The characterizations given on this page are based upon the results obtained from Test No. QN0926A0, which is not reported herein. The 135-lb warhead tested in QN0926A0 incorporated the recommended design details given on page 40 of this report, for the 700-grain version of a 135-lb fireformed HIBAL warhead. The results obtained from QN0926A0 will be reported fully in a subsequent report. The characterizations on this page will be used in the second phase HIBAL end-game analysis since they reflect the performance of the recommended designs.

# TABLE 3.3.5

## WARHEAD CHARACTERIZATIONS

PREDICTED FOR 11.5-INCH DIAMETER x 200-LB WARHEADS
CONTAINING PREFORMED HEX HIBAL FRAGMENTS
(BASED ON DATA OBTAINED IN TEST NO. QN0429A0)

| | FRAGMENT DETAILS | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 1161 | 851 | 640 |
| WIDTH ACROSS FLATS (inch) | 3/4 | 7/8 | 1 |
| THICKNESS (inch) | 0.548 | 0.548 | 0.548 |
| | | | |

| | FRAGMENT EJECTION CHARACTERISTICS (1) | | | | | |
|---|---|---|---|---|---|---|
| ROW NO. | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| A (2) (3) | | | | | | |
| 1 | +11.5 | 4100 | +10.0 | 4100 | +7.5 | 4100 |
| 2 | + 7.0 | 4200 | + 5.0 | 4200 | +4.5 | 4250 |
| 3 | + 4.0 | 4300 | + 2.5 | 4350 | +2.0 | 4400 |
| 4 | + 2.5 | 4400 | + 1.0 | 4500 | 0.0 | 4550 |
| 5 | + 1.0 | 4500 | - 1.0 | 4600 | -1.0 | 4700 |
| 6 | + 0.5 | 4650 | - 1.0 | 4700 | -2.0 | 4800 |
| 7 | - 0.5 | 4700 | - 2.0 | 4850 | -2.5 | 4950 |
| 8 | - 1.0 | 4800 | - 2.5 | 4950 | -3.0 | 5100 |
| 9 | - 1.5 | 4900 | - 3.0 | 5050 | -3.0 | 5200 |
| 10 | - 2.0 | 5000 | - 3.0 | 5150 | -3.5 | 5300 |
| 11 | - 2.0 | 5100 | - 3.5 | 5250 | -4.0 | 5350 |
| 12 | - 2.5 | 5200 | - 3.5 | 5300 | -4.0 | 5450 |
| 13 | - 3.0 | 5250 | - 4.0 | 5400 | -4.0 | 5500 |
| 14 | - 3.0 | 5300 | - 4.0 | 5450 | -4.5 | 5500 |
| 15 | - 3.0 | 5400 | - 4.0 | 5500 | -4.5 | 5500 |
| 16 | - 3.5 | 5450 | - 4.0 | 5500 | -4.5 | 5500 |
| 17 | - 3.5 | 5500 | - 4.0 | 5500 | -4.5 | 5450 |
| 18 | - 4.0 | 5500 | - 4.5 | 5500 | -5.0 | 5350 |
| 19 | - 4.0 | 5500 | - 4.5 | 5500 | -5.0 | 5200 |
| 20 | - 4.0 | 5500 | - 4.5 | 5400 | -5.0 | 4950 |
| 21 | - 4.0 | 5500 | - 5.0 | 5300 | | |
| 22 | - 4.0 | 5500 | - 5.0 | 5150 | | |
| 23 | - 4.0 | 5450 | - 5.0 | 4950 | | |
| 24 | - 4.0 | 5350 | | | | |
| 25 | - 4.0 | 5250 | | | | |
| 26 | - 4.0 | 5100 | | | | |
| 27 | - 4.0 | 4950 | | | | |
| B (2) | | | | | | |

**NOTES:**

(1) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(2) A and B are end-ring rows.
(3) Booster end.

# TABLE 3.3.6

## WARHEAD CHARACTERIZATIONS (4)
## PREDICTED FOR 11.5-INCH DIAMETER x 200-LB WARHEADS CONTAINING FIREFORMED HIBAL FRAGMENTS

(BASED ON DATA OBTAINED IN TEST NOS. QN0328A0 AND QN0429A0)

| | FRAGMENT DETAILS (1) | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 1144 | 836 | 650 |
| CIRCUMFERENTIAL WIDTH: INSIDE | 0.741 | 0.858 | 0.959 |
| CIRCUMFERENTIAL WIDTH: OUTSIDE | 0.871 | 0.951 | 1.063 |
| LONGITUDINAL WIDTH: | 0.769 | 0.909 | 1.000 |
| THICKNESS | 0.563 | 0.563 | 0.563 |

| | FRAGMENT EJECTION CHARACTERISTICS (2) | | | | | |
|---|---|---|---|---|---|---|
| FRAGMENT ROW | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| 1 (3) | +5.0 | 4100 | +5.0 | 4100 | +5.0 | 4100 |
| 2 | +3.5 | 4200 | +3.5 | 4200 | +3.0 | 4200 |
| 3 | +2.5 | 4300 | +2.0 | 4400 | +2.0 | 4400 |
| 4 | +1.5 | 4400 | +1.0 | 4500 | +0.5 | 4600 |
| 5 | +0.5 | 4500 | 0.0 | 4600 | -0.5 | 4700 |
| 6 | -0.5 | 4600 | -1.0 | 4700 | -1.5 | 4900 |
| 7 | -1.0 | 4700 | -2.0 | 4900 | -2.0 | 5000 |
| 8 | -1.5 | 4800 | -2.5 | 5000 | -3.0 | 5100 |
| 9 | -2.0 | 4900 | -3.0 | 5100 | -3.0 | 5200 |
| 10 | -3.0 | 5000 | -3.0 | 5200 | -3.5 | 5300 |
| 11 | -3.0 | 5100 | -3.5 | 5300 | -4.0 | 5400 |
| 12 | -3.5 | 5200 | -4.0 | 5400 | -4.0 | 5500 |
| 13 | -3.5 | 5300 | -4.0 | 5400 | -4.5 | 5500 |
| 14 | -4.0 | 5400 | -4.0 | 5500 | -4.5 | 5500 |
| 15 | -4.0 | 5400 | -4.5 | 5500 | -4.5 | 5500 |
| 16 | -4.0 | 5500 | -4.5 | 5500 | -5.0 | 5500 |
| 17 | -4.5 | 5500 | -5.0 | 5500 | -5.0 | 5400 |
| 18 | -4.5 | 5500 | -5.0 | 5400 | -5.0 | 5300 |
| 19 | -4.5 | 5500 | -5.0 | 5400 | -5.0 | 5200 |
| 20 | -4.5 | 5500 | -5.0 | 5300 | -5.0 | 5100 |
| 21 | -5.0 | 5500 | -5.0 | 5200 | | |
| 22 | -5.0 | 5500 | -5.0 | 5000 | | |
| 23 | -5.0 | 5400 | | | | |
| 24 | -5.0 | 5300 | | | | |
| 25 | -5.0 | 5100 | | | | |
| 26 | -5.0 | 4900 | | | | |

NOTES:

(1) All linear dimensions are in inches.
(2) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(3) Booster end.

(4) The characterizations shown on this page reflect the data from the relevant tests reported herein, but are not to be used for the second phase HIBAL end-game analysis. See Note 4 on page 28A.

# TABLE 3.3.6A

## WARHEAD CHARACTERIZATIONS
## PREDICTED FOR 11.5-INCH DIAMETER x 200-LB WARHEADS
## CONTAINING FIREFORMED HIBAL FRAGMENTS
## (BASED ON DATA OBTAINED IN TEST NO. QN092GAO) (4)

| | FRAGMENT DETAILS (1) | | | | | |
|---|---|---|---|---|---|---|
| FRAG. WT. | 500-grain | | 700-grain | | [illegible] | |
| TOTAL NO. | 1144 | | 836 | | [illegible] | |
| CIRCUMFERENTIAL WIDTH: INSIDE | 0.741 | | [illegible] | | [illegible] | |
| OUTSIDE | 0.821 | | 0.951 | | 1.063 | |
| LONGITUDINAL WIDTH: | 0.769 | | 0.909 | | 1.000 | |
| THICKNESS | 0.563 | | 0.563 | | 0.563 | |
| | FRAGMENT EJECTION CHARACTERISTICS (2) | | | | | |
| FRAGMENT ROW | POLAR ANGLE (degrees) | VELOCITY AVG. 0-15' (ft/sec) | POLAR ANGLE (degrees) | VELOCITY AVG. 0-15' (ft/sec) | POLAR ANGLE (degrees) | VELOCITY AVG. 0-15' (ft/sec) |
| 1 (3) | +27 | [illegible] | +23 | [illegible] | [illegible] | [illegible] |
| 2 | +12 | [illegible] | +10 | [illegible] | [illegible] | [illegible] |
| 3 | + 6 | [illegible] | + 4 | [illegible] | + 4 | [illegible] |
| 4 | + 3 | 4400 | + 2 | [illegible] | + 1 | [illegible] |
| 5 | + 1 | 4700 | 0 | [illegible] | [illegible] | [illegible] |
| 6 | 0 | 4800 | - 1 | [illegible] | [illegible] | [illegible] |
| 7 | - 1 | 5000 | - 2 | 5100 | [illegible] | [illegible] |
| 8 | - 2 | 5000 | - 3 | [illegible] | - 3 | [illegible] |
| 9 | - 2 | 5100 | - 3 | 5200 | - 4 | [illegible] |
| 10 | - 3 | 5200 | - 4 | [illegible] | - 4 | [illegible] |
| 11 | - 3 | [illegible] | - 4 | [illegible] | - 4 | [illegible] |
| 12 | - 4 | 5300 | - 5 | [illegible] | - 5 | [illegible] |
| 13 | - 4 | 5300 | - 5 | [illegible] | - 5 | [illegible] |
| 14 | - 4 | 5300 | - 5 | 5400 | - 5 | 5400 |
| 15 | - 5 | 5400 | - 5 | 5400 | - 5 | [illegible] |
| 16 | - 5 | [illegible] | - 5 | 5400 | - 6 | [illegible] |
| 17 | - 5 | 5400 | - 6 | 5400 | - 6 | [illegible] |
| 18 | - 5 | 5400 | - 6 | [illegible] | - 7 | [illegible] |
| 19 | - 5 | 5400 | - 6 | 5300 | - 7 | 5100 |
| 20 | - 6 | 5400 | - 7 | 5200 | -10 | 4800 |
| 21 | - 6 | 5300 | - 8 | 5000 | | |
| 22 | - 6 | 5300 | -10 | 4800 | | |
| 23 | - 7 | 5200 | | | | |
| 24 | - 7 | 5100 | | | | |
| 25 | - 8 | 5000 | | | | |
| 26 | -11 | 4800 | | | | |

NOTES:

(1) All linear dimensions are in inches.
(2) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(3) Booster end.
(4) The characterizations given on this page are based upon the results obtained from Test No. QN092GAO, which is not reported herein. The 135-lb warhead tested in QN092GAO incorporated the recommended design details given on page 40 of this report, for the 700-grain version of a 135-lb fireformed HIBAL warhead. The results obtained from QN092GAO will be reported fully in a subsequent report. The characterizations on this page will be used in the second phase HIBAL end-game analysis since they reflect the performance of the recommended designs.

# TABLE 3.3.7

## WARHEAD CHARACTERIZATIONS

PREDICTED FOR 19-INCH DIAMETER x 200-LB ANNULAR WARHEADS CONTAINING PREFORMED HEX HIBAL FRAGMENTS

(BASED ON DATA OBTAINED IN TEST NO. QN0409AO)

| | FRAGMENT DETAILS | | | | | |
|---|---|---|---|---|---|---|
| FRAG. WT. | 500-grain | | 700-grain | | 900-grain | |
| TOTAL NO. | 975 | | 741 | | 550 | |
| WIDTH ACROSS FLATS (inch) | 7/8 | | 1 | | 1-1/8 | |
| THICKNESS (inch) | 0.42 | | 0.42 | | 0.42 | |
| "K" VALUE (in fuel) | 70 | | 74 | | 71 | |
| | FRAGMENT EJECTION CHARACTERISTICS (1) | | | | | |
| ROW NO. | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| 1 (2) | +17.0 | 3600 | +15.0 | 3650 | +13.0 | 3700 |
| 2 | +12.5 | 3950 | + 5.0 | 4000 | + 3.5 | 4150 |
| 3 | + 2.0 | 4200 | + 1.0 | 4300 | - 0.5 | 4500 |
| 4 | 0.0 | 4450 | - 1.0 | 4550 | - 2.0 | 4800 |
| 5 | - 2.0 | 4650 | - 2.5 | 4750 | - 3.5 | 5000 |
| 6 | - 3.0 | 4800 | - 3.5 | 4950 | - 5.0 | 5100 |
| 7 | - 4.0 | 4950 | - 4.5 | 5050 | - 5.0 | 5100 |
| 8 | - 4.5 | 5050 | - 5.0 | 5100 | - 5.5 | 5000 |
| 9 | - 5.0 | 5100 | - 5.0 | 5100 | - 6.0 | 4800 |
| 10 | - 5.0 | 5100 | - 6.0 | 5000 | - 9.0 | 4700 |
| 11 | - 5.5 | 5050 | - 6.0 | 4900 | -10.0 | 4500 |
| 12 | - 6.0 | 4950 | - 7.0 | 4750 | | |
| 13 | - 6.0 | 4850 | -10.5 | 4600 | | |
| 14 | - 7.0 | 4700 | | | | |
| 15 | -11.0 | 4600 | | | | |

**NOTES:**

(1) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.

(2) Booster end.

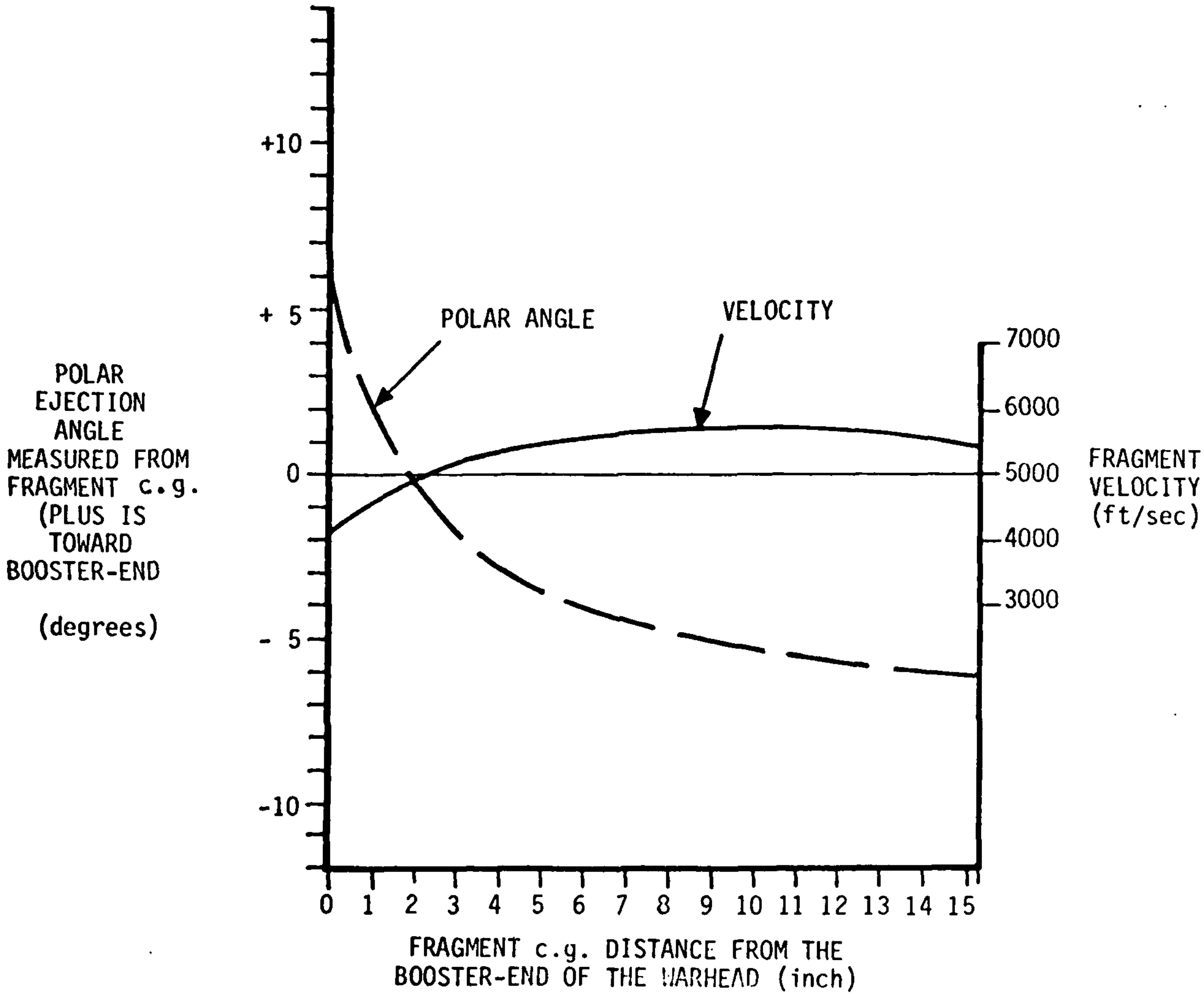
TABLE 3.3.8
WARHEAD CHARACTERIZATIONS
PREDICTED FOR 19-INCH DIAMETER x 200-LB WARHEADS
CONTAINING FIREFORMED HIBAL FRAGMENTS
(EXTRAPOLATED FROM DATA OBTAINED IN TEST NO. QN0409A0)

| | FRAGMENT DETAILS (1) | | |
|---|---|---|---|
| FRAG. WT. | 500-grain | 700-grain | 900-grain |
| TOTAL NO. | 980 | 720 | 540 |
| CIRCUMFERENTIAL WIDTH: | 70/row | 60/row | 54/row |
| INSIDE | 0.808 | 0.942 | 1.047 |
| OUTSIDE | 0.853 | 0.995 | 1.105 |
| LONGITUDINAL WIDTH: | 0.786 | 0.917 | 1.100 |
| THICKNESS | 0.5 | 0.5 | 0.5 |

| | FRAGMENT EJECTION CHARACTERISTICS (2) | | | | | |
|---|---|---|---|---|---|---|
| ROW NO. | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) | POLAR ANGLE (degrees) | VELOCITY (ft/sec) |
| 1 (3) | +17.0 | 3600 | +16.0 | 3600 | +15.0 | 3700 |
| 2 | + 6.0 | 3900 | + 5.0 | 4000 | + 3.0 | 4100 |
| 3 | + 2.0 | 4200 | - 0.5 | 4300 | - 0.5 | 4500 |
| 4 | - 0.5 | 4500 | - 1.5 | 4600 | - 3.0 | 4800 |
| 5 | - 2.0 (4) | 4700 | - 3.0 (4) | 4800 | - 4.0 (4) | 5000 |
| 6 | - 3.5 (4) | 4900 | - 4.0 (4) | 5000 | - 5.0 (4) | 5200 |
| 7 | - 4.0 (4) | 5000 | - 5.0 (4) | 5200 | - 5.0 (4) | 5200 |
| 8 | - 5.0 (4) | 5200 | - 5.0 (4) | 5200 | - 5.5 (4) | 5100 |
| 9 | - 5.0 (4) | 5200 | - 5.5 (4) | 5200 | - 7.0 (4) | 4900 |
| 10 | - 5.5 (4) | 5200 | - 6.0 (4) | 5000 | -11.0 (4) | 4700 |
| 11 | - 6.0 (4) | 5100 | - 7.5 (4) | 4900 | | |
| 12 | - 6.5 (4) | 5000 | -11.5 (4) | 4600 | | |
| 13 | - 8.0 (4) | 4800 | | | | |
| 14 | -13.0 (4) | 4600 | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |
| 21 | | | | | | |
| 22 | | | | | | |
| 23 | | | | | | |
| 24 | | | | | | |
| 25 | | | | | | |

**NOTES:**

(1) All linear dimensions are in inches.
(2) Polar angle is given from the fragment c.g. relative to a normal to the warhead axis through that c.g. Plus angles are toward the booster end. Velocity is the estimated average velocity measured over the first fifteen feet of travel in a static arena test, including losses through shroud(s) and insulation.
(3) Booster end.
(4) These values conform to data for preformed fragments. Values for fireformed fragments may differ when proper fireforming is achieved.

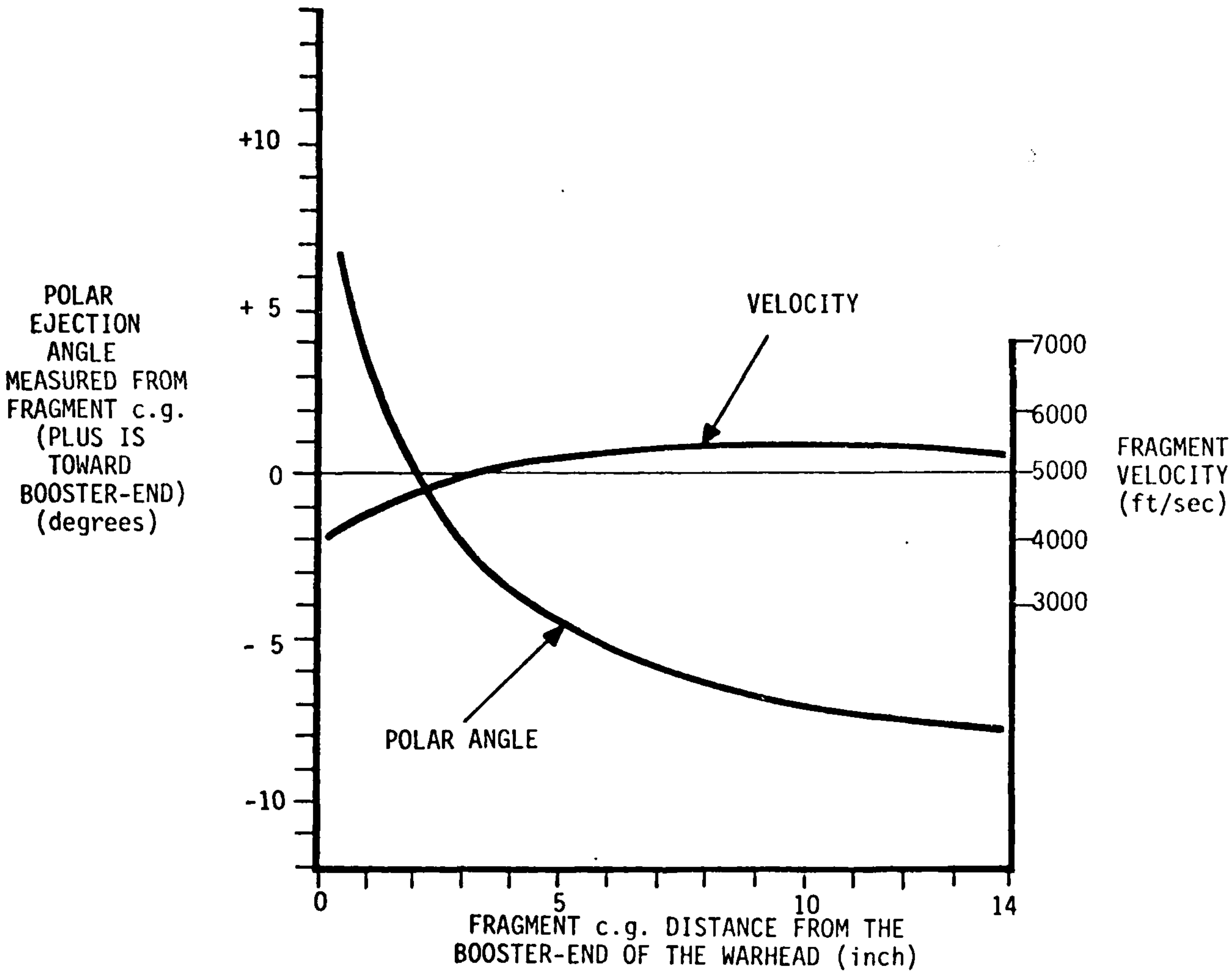



PREDICTED FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR AN 80-LB SOLID WARHEAD

Having an 8-inch O.D. x 2-inch I.D. x 15-inch long x 0.460-inch case thickness, and containing preformed hex-HIBAL fragments sandwiched between an outer skin of 0.030-inch thick steel and an inner skin of 0.010-inch thick steel.

Prediction is based upon the data acquired in Test No. QN0319A0.

FIGURE 3.4.1

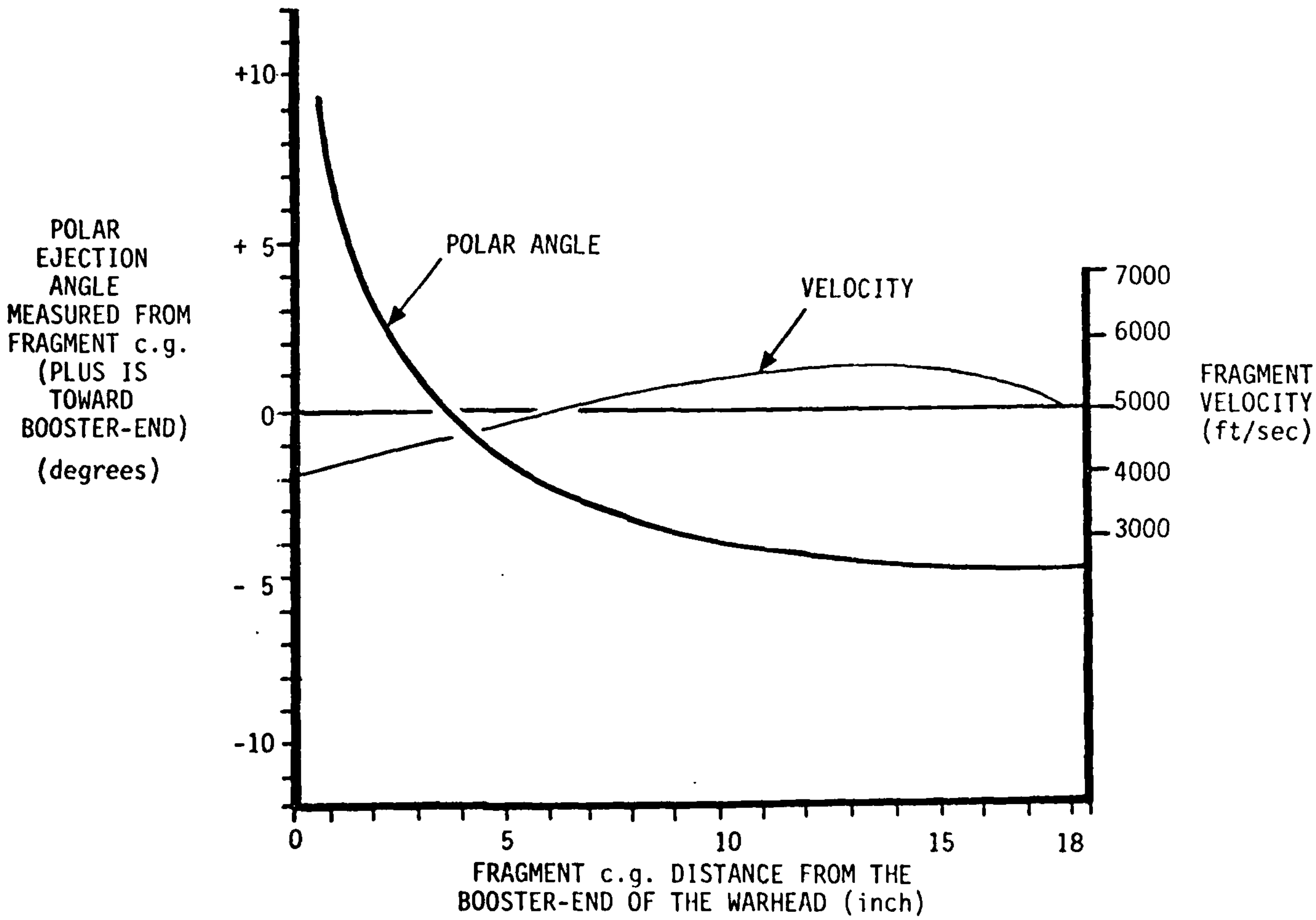



PREDICTED FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 135-LB SOLID WARHEAD

Having an 11.5-inch O.D. x 2.88-inch I.D. x 14-inch long x 0.51-inch case thickness, and containing preformed hex HIBAL fragments sandwiched between an outer skin of 0.015-inch thick steel and an inner skin of 0.010-inch thick steel.
Prediction is based upon the data acquired in Test No. QN0514A0.



FIGURE 3.4.2



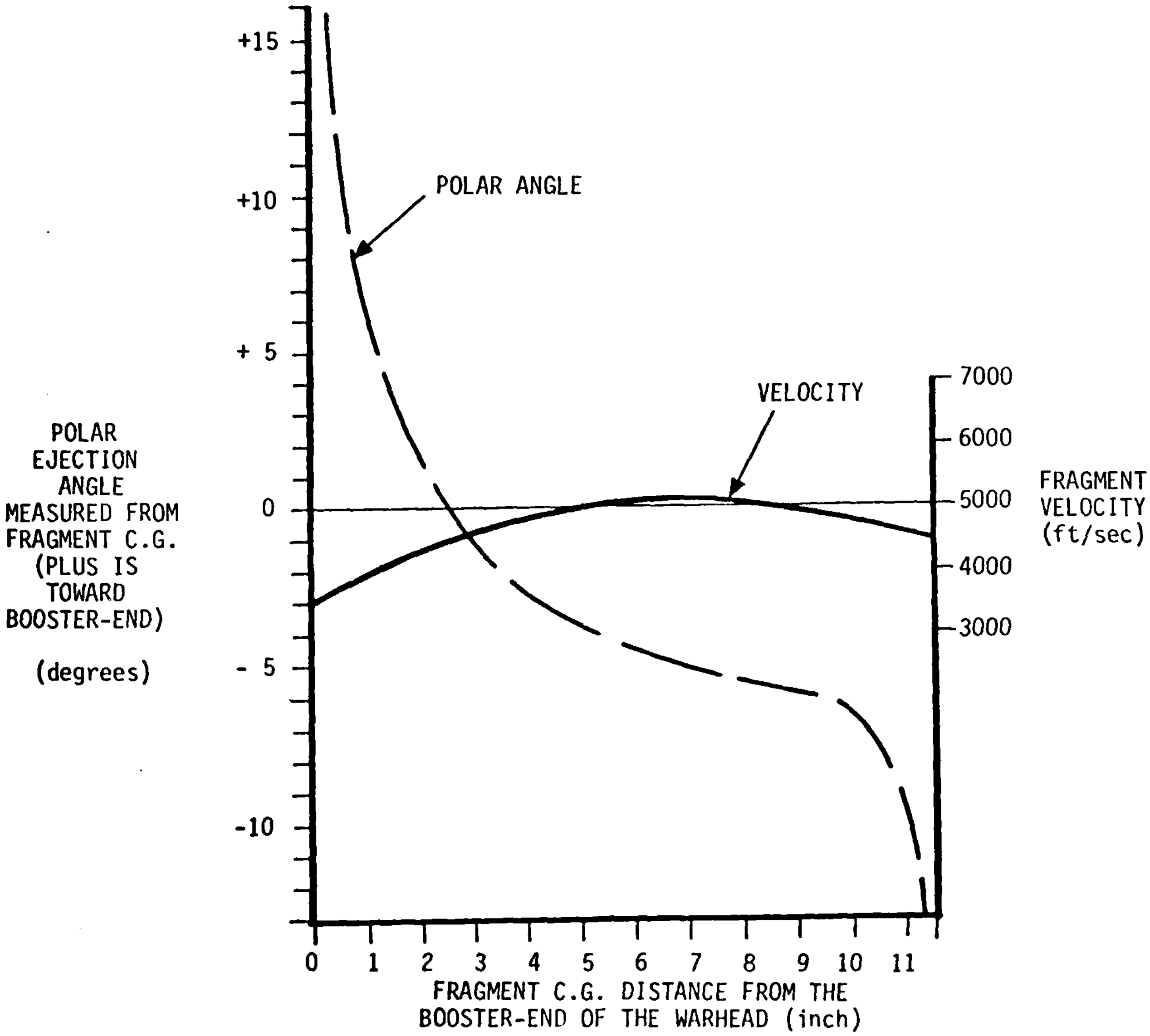

PREDICTED FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 200-LB SOLID WARHEAD

Having an 11.5-inch O.D. x 2.88-inch I.D. x 18.38-inch long x 0.573-inch case thickness and containing preformed hex HIBAL fragments sandwiched between an outer skin of 0.015-inch thick steel and an inner skin of 0.010-inch steel.

Prediction is based upon the data acquired in Test No. QN0429A0.



FIGURE 3.4.3




PREDICTED FRAGMENT EJECTION CHARACTERISTICS

(POLAR ANGLE & VELOCITY)

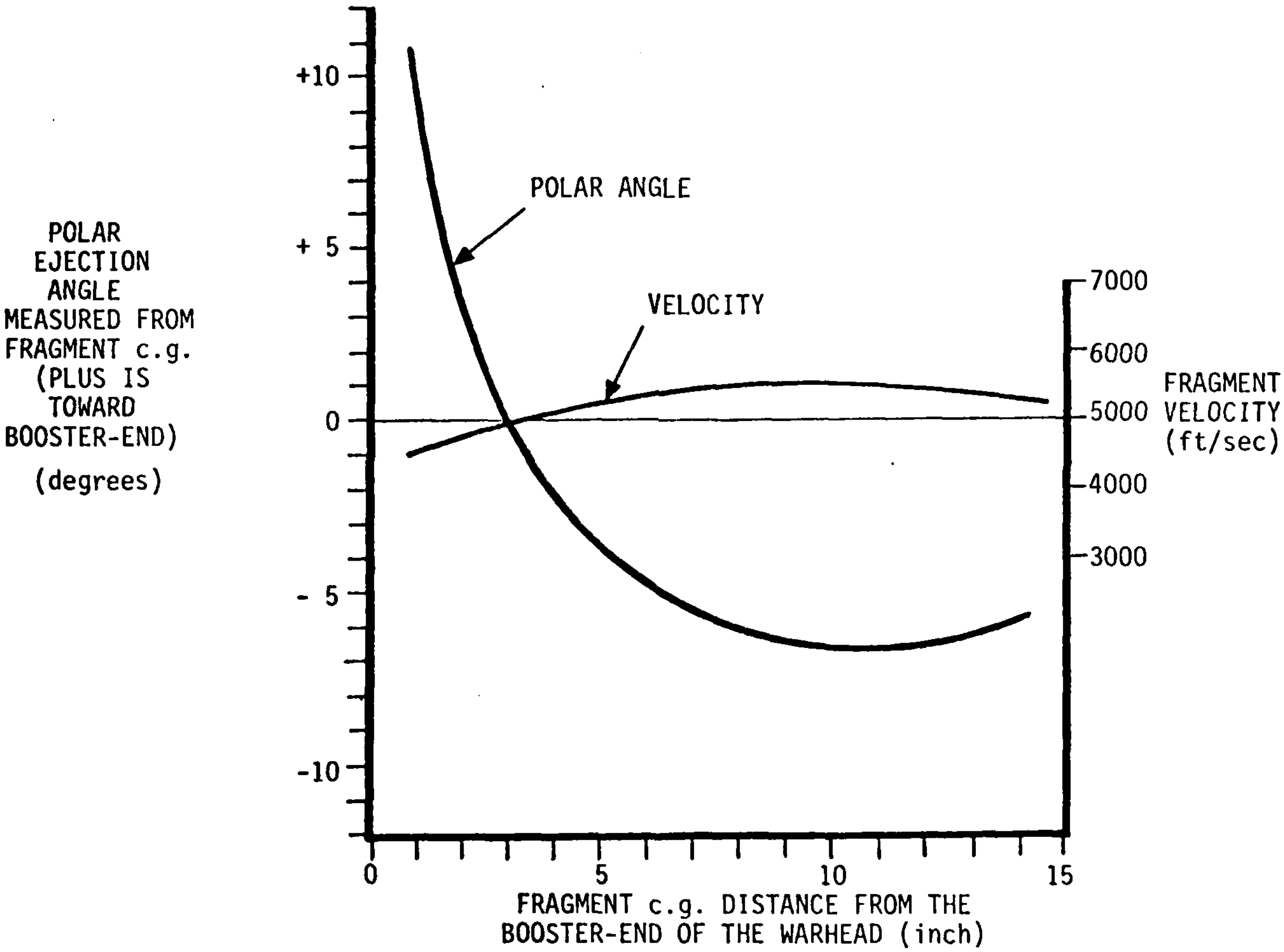
FOR A 200-LB ANNULAR WARHEAD

Having a 19-inch O.D. x 10.6-inch I.D. x 11.5-inch long x 0.46-inch case thickness and containing preformed hex-HIBAL fragments sandwiched between an outer skin of 0.030-inch thick steel and an inner skin of 0.010-inch thick steel.

Prediction is based upon an extrapolation of the preformed fragment data in Test No. QN0409A0.



FIGURE 3.4.4

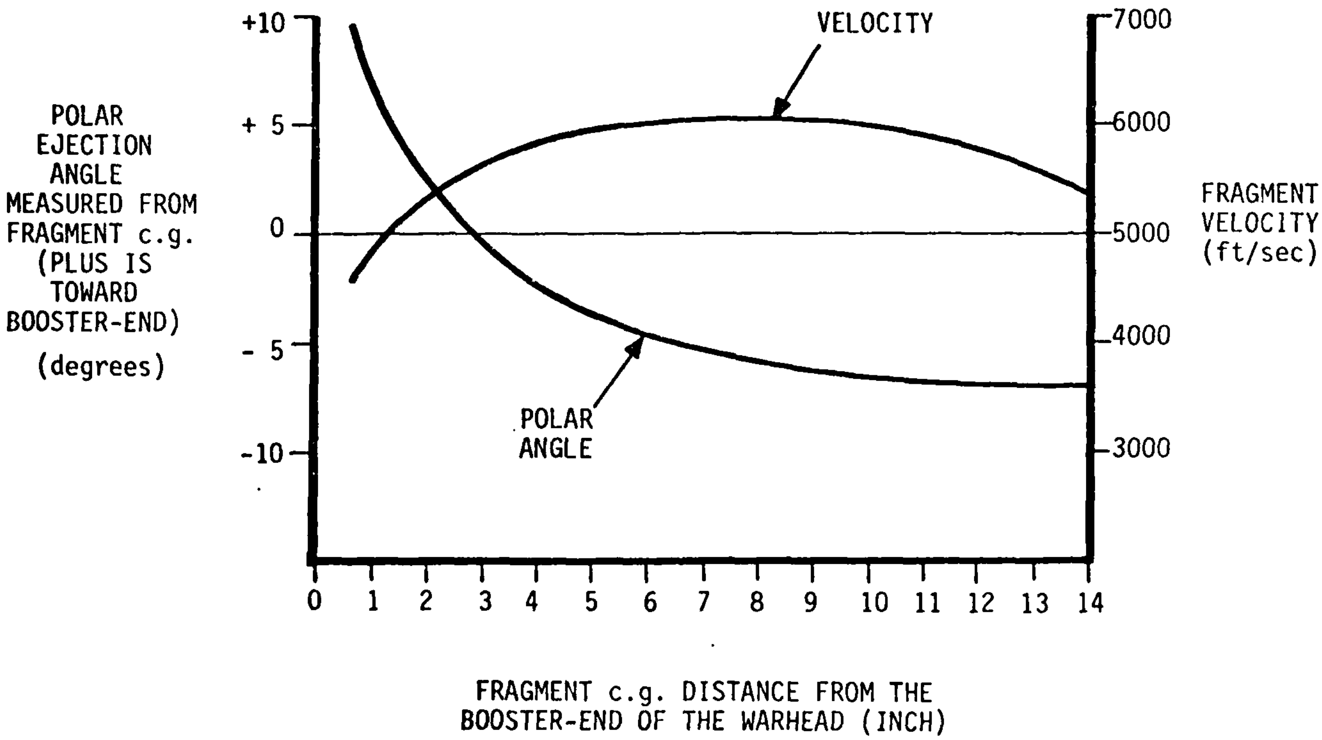



FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR AN 80-LB SOLID (FIREFORMED FRAGMENT) WARHEAD

Having an 8-inch O.D. x 2-inch I.D. x 15-inch long x 0.438-inch case thickness. Prediction is based upon data acquired in Test QN0225A0.



FIGURE 3.4.5

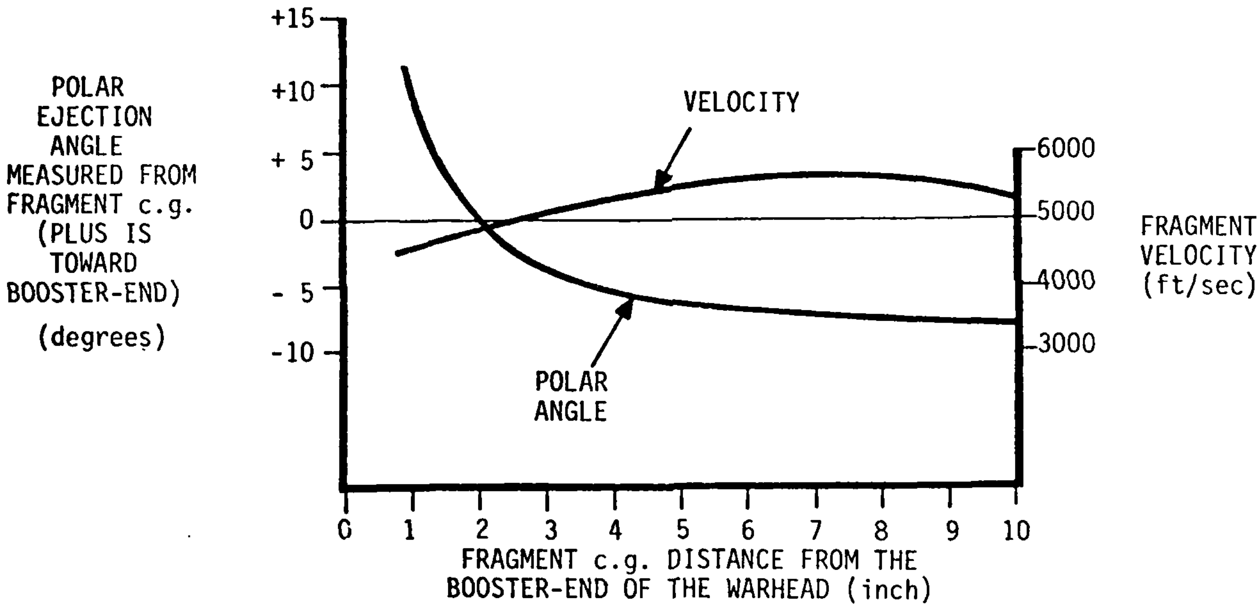



FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 135-LB FIREFORMED FRAGMENT WARHEAD

Having a 11.5-inch O.D. x 14-inch long x 2.88-inch I.D. x 0.5-inch case thickness.
Prediction is based on data acquired in Test QN0311A0



FIGURE 3.4.6




FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 200-LB (FIREFORMED FRAGMENT) SOLID WARHEAD

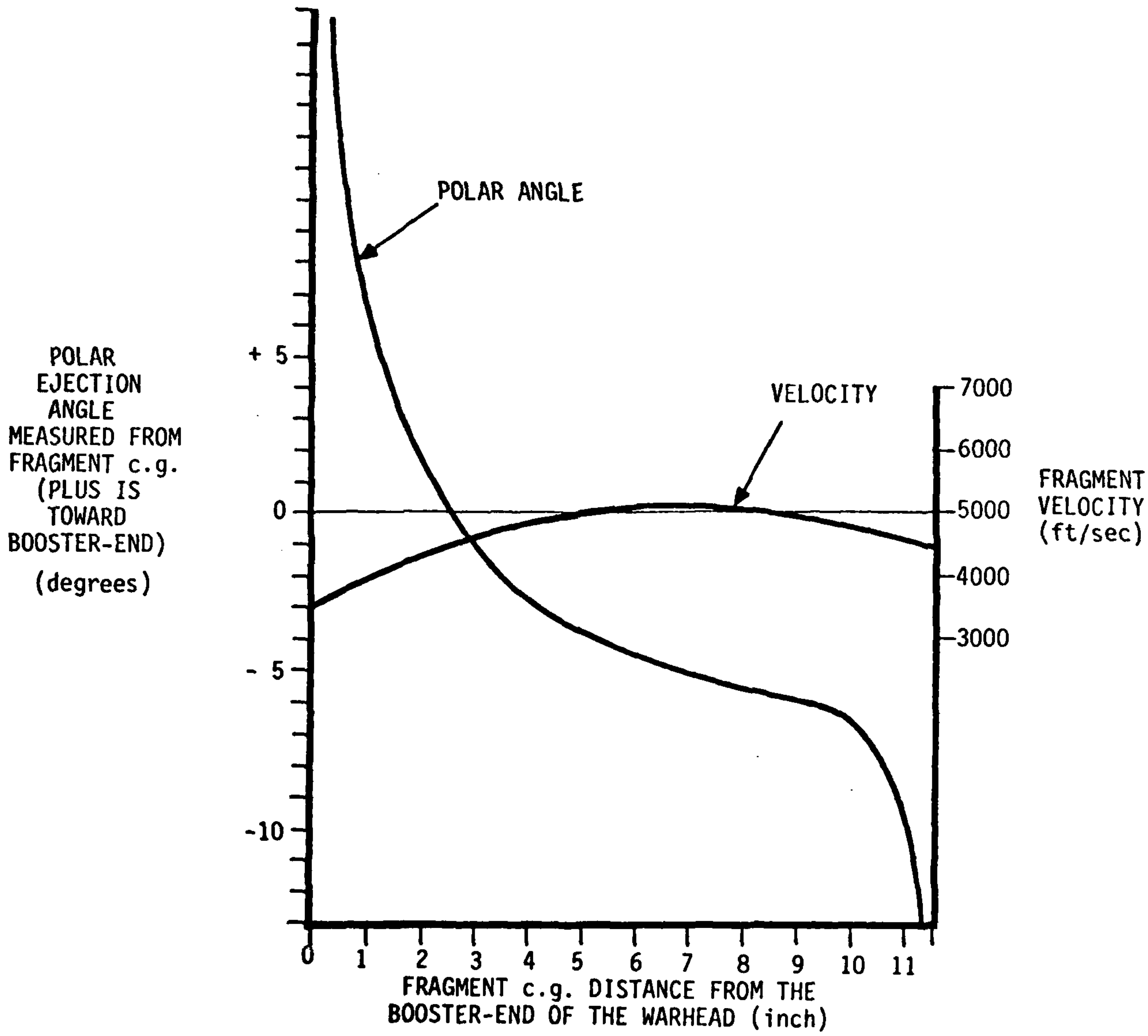
Having a 11.5-inch O.D. x 2.88-inch I.D. x 20-inches long x 0.563-inch case thickness.
Prediction is based on an extrapolation of the data from Test QN0328A0

FIGURE 3.4.7

AD-A092 071 NEW MEXICO INST OF MINING AND TECHNOLOGY SOCORRO TER--ETC F/G 19/1
HIBAL PROGRAM PRELIMINARY WARHEAD-DESIGN. VOLUME I.(U)
SEP 80 N00024-79-C-5333
UNCLASSIFIED NMT/TERA-T-80-1356-U-VOL- NL

3 of 3

END
DATE
FILMED
1 8
DTIC




FRAGMENT EJECTION CHARACTERISTICS
(POLAR ANGLE & VELOCITY)
FOR A 200-LB ANNULAR WARHEAD

With a 19-inch O.D., 10.6-inch I.D., 11-inches long and a 0.5-inch case thickness, curves are extrapolated from data obtained in Test QN0409A0



FIGURE 3.4.8

## TABLE 3.3.9
## DESIGN FOR WARHEADS
## USING
## PREFORMED HEX HIBAL FRAGMENTS

| ITEM | | 8-inch x 80-lb | 11.5-inch x 135-lb | 11.5-inch x 200-lb | 19-inch x 200-lb |
|---|---|---|---|---|---|
| DIMENSIONS | | | | | |
| | O.D. | 8.0 | 11.5 | 11.5 | 19.0 |
| | I.D. | 2.0 | 2-7/8 | 2-7/8 | 10.5 |
| | LENGTH | 15.2 | 14.0 | 18-3/8 | 11.5 |
| | OUTER SKIN THK. | 0.025 | 0.015 | 0.015 | 0.030 |
| | INNER SKIN THK. | 0.010 | 0.010 | 0.010 | 0.010 |
| | S & A TUBE THK. | 0.063 | 0.063 | 0.063 | N/A |
| | END-PLATE THK. | 0.125 | 0.125 | 0.125 | 0.125 |
| FRAGMENT DETAILS | | | | | |
| 500-grain | THICKNESS | 0.42 | 0.485 | 0.548 | 0.42 |
| | WIDTH | 0.875 | 0.813 | 0.75 | 0.875 |
| | NO. PER ROW | 25.0 | 40.0 | 43.0 | 65.0 |
| | NO. OF ROWS | 18.0 | 18.0 | 27.0 | 15.0 |
| | TOTAL NO. | 450.0 | 720.0 | 1161.0 | 975.0 |
| 700-grain | THICKNESS | 0.42 | 0.485 | 0.548 | 0.42 |
| | WIDTH | 1.0 | 0.938 | 0.875 | 1.0 |
| | NO. PER ROW | 22.0 | 35.0 | 37.0 | 57.0 |
| | NO. OF ROWS | 16.0 | 16.0 | 23.0 | 13.0 |
| | TOTAL NO. | 352.0 | 560.0 | 851.0 | 741.0 |
| 900-grain | THICKNESS | 0.42 | 0.485 | 0.548 | 0.42 |
| | WIDTH | 1.125 | 1.063 | 1.0 | 1.125 |
| | NO. PER ROW | 19.0 | 31.0 | 32.0 | 50.0 |
| | NO. OF ROWS | 14.0 | 13.0 | 20.0 | 11.0 |
| | TOTAL NO. | 266.0 | 403.0 | 640.0 | 550.0 |
| MATERIALS | | | | | |
| | OUTER SKIN | MILD STEEL | | | |
| | INNER SKIN | | | | |
| | S & A TUBE | | | | |
| | END PLATES | | | | |
| | HIGH EXPLOSIVE | TO BE DETERMINED | | | |
| | FRAGMENTS | SAE 4130 ALLOY STEEL, OIL QUENCHED FROM 1550°F, DRAW AT 800°F to RC42 | | | |
| BOOSTER DETAILS | | | | | |
| | LOCATION | AT ONE END | | | |
| | COMPOSITION | TO BE DETERMINED | | | |
| | SIZE | | | | |
| END-RING HOOPS | | | | | |
| (EA. END) | WIDTH | 0.5 | 0.5 | 0.375 | 0.25 |
| | RADIAL THK. | 0.44 | 0.5 | 0.56 | 0.44 |
| | MATERIAL | MILD STEEL | | | |

ALL DIMENSIONS ARE IN INCHES.

TABLE 3.3.10

DESIGN FOR WARHEADS

USING

FIREFORMED HIBAL FRAGMENTS

| ITEM | | 8-inch x 80-lb | 11.5-inch x 135-lb | 11.5-inch x 200-lb | 19-inch x 200-lb |
|---|---|---|---|---|---|
| DIMENSIONS | | | | | |
| | O.D. | 8.0 | 11.5 | 11.5 | 19.0 |
| | I.D. | 2.0 | 2.88 | 2.88 | 10.5 |
| | CASE THK. | 0.438 | 0.500 | 0.563 | 0.500 |
| | S & A TUBE THK. | 0.063 | 0.063 | 0.063 | N/A |
| | END-PLATE THK. | 0.125 | 0.125 | 0.125 | 0.125 |
| FRAGMENT DETAILS* | | | | | |
| INTENDED WEIGHT | LONGITUDINAL GROOVES | | | | |
| 500-grain | DEPTH, INSIDE | 0.110 | 0.140 | 0.170 | 0.140 |
| | OUTSIDE | 0.110 | 0.140 | 0.170 | 0.140 |
| | SPACING (INSIDE) | 0.799 | 0.767 | 0.741 | 0.808 |
| | CIRCUMFERENTIAL GROOVES | | | | |
| | DEPTH, INSIDE | 0.115 | 0.115 | 0.115 | 0.115 |
| | OUTSIDE | 0.205 | 0.285 | 0.350 | 0.285 |
| | SPACING (INSIDE) | 0.833 | 0.824 | 0.769 | 0.786 |
| | FRAGMENTS PER ROW | 28.0 | 43.0 | 44.0 | 70.0 |
| | NUMBER OF ROWS | 18.0 | 17.0 | 26.0 | 14.0 |
| | TOTAL NO. OF FRAGMENTS | 504.0 | 731.0 | 1144.0 | 980.0 |
| INTENDED WEIGHT | LONGITUDINAL GROOVES | | | | |
| 700-grain | DEPTH, INSIDE | 0.110 | 0.140 | 0.170 | 0.140 |
| | OUTSIDE | 0.110 | 0.140 | 0.170 | 0.140 |
| | SPACING (INSIDE) | 0.895 | 0.892 | 0.858 | 0.942 |
| | CIRCUMFERENTIAL GROOVES | | | | |
| | DEPTH, INSIDE | 0.115 | 0.115 | 0.115 | 0.115 |
| | OUTSIDE | 0.205 | 0.285 | 0.350 | 0.285 |
| | SPACING (INSIDE) | 1.0 | 0.933 | 0.909 | 0.917 |
| | FRAGMENTS PER ROW | 25.0 | 37.0 | 38.0 | 60.0 |
| | NUMBER OF ROWS | 15.0 | 15.0 | 22.0 | 12.0 |
| | TOTAL NO. OF FRAGMENTS | 375.0 | 555.0 | 836.0 | 720.0 |
| INTENDED WEIGHT | LONGITUDINAL GROOVES | | | | |
| 900-grain | DEPTH, INSIDE | 0.110 | 0.140 | 0.170 | 0.140 |
| | OUTSIDE | 0.110 | 0.140 | 0.170 | 0.140 |
| | SPACING (INSIDE) | 1.017 | 1.000 | 0.959 | 1.047 |
| | CIRCUMFERENTIAL GROOVES | | | | |
| | DEPTH, INSIDE | 0.115 | 0.115 | 0.115 | 0.115 |
| | OUTSIDE | 0.205 | 0.285 | 0.350 | 0.285 |
| | SPACING (INSIDE) | 1.154 | 1.077 | 1.000 | 1.100 |
| | FRAGMENTS PER ROW | 22.0 | 33.0 | 34.0 | 54.0 |
| | NUMBER OF ROWS | 13.0 | 13.0 | 20.0 | 10.0 |
| | TOTAL NO. OF FRAGMENTS | 286.0 | 429.0 | 680.0 | 540.0 |
| MATERIALS | | | | | |
| | WARHEAD CASE | ALL FIREFORMED FRAGMENTS MADE OF 4130 STEEL, QUENCHED AND DRAWN TO RC42 | | | |
| | S & A TUBE | MILD STEEL | | | |
| | END-PLATES | | | | |
| | HIGH EXPLOSIVE | | | | |

* THE INCLUDED ANGLE OF ALL GROOVES IS TO BE 37°, ALL DIMENSIONS ARE IN INCHES.

Distribution

Commander
Naval Sea Systems Command
Washington, DC 20362
Attn: SEA-62R
SEA-62R54
SEA-62Z3
SEA-62Z5
PMS-400M

Assistant Secretary of the Navy
Attn: (RE&S) R. Rumpf
Washington, DC 20362

Chief of Naval Operations
Department of the Navy
Washington, DC 20362
Attn: OP352L (CDR Webb)
OP982F31 (CDR Fricke)

Commander
Naval Air Systems Command
Washington, DC 20362
Attn: AIR-5413 (J. Newquist)
AIR-350 (H. Benefiel)
PMA-241
PMA-262

Commander
Naval Surface Weapons Center
Dahlgren, VA 22448
Attn: Code G34
G34(A. Hales)
G35(S. Waggener)
G13(T. Wasmund)

Commander
Naval Weapons Center
China Lake, CA 93555
Attn: Code 3261 (T. Zulkoski)
Code 383 (J. Pearson)
Code 338 (K. Grant)

Applied Physics Laboratory/Johns Hopkins University
Johns Hopkins Road
Laurel, MD 20810
Attn: B. Woodford
C. Brown-Group BFD

Director
USA Ballistic Research Laboratories (DRDAR-BLV)
Attn: D. Mowrer
Aberdeen Proving Ground
Aberdeen, MD 21005

Distribution (Cont'd)

Commander
USA Missile Research & Development Command
Attn: E. Atkins, Adv. Concepts Group
LTCOL R. Kelly, Code DRSMI-OD
Huntsville, Alabama

Commander
Armaments Research and Development Command
Dover, NJ 07801
Attn: DRDAR-LCE-M (T. Stevens)
DRDAR-LCA-L

Commander
Air Force Armaments Laboratory
Eglin AFB, Fl 32542
Attn: AFATL/DLJW (D. Glendenning)
AFATL/DLYD (K. McArdle)
ADTC/SD7ED (P. Buckley)

Commander
Naval Postgraduate School
Monterey, CA
Attn: Professor Ball

McDonnell Douglas
P.O. Box 516
St. Louis, MO 63166
Attn: J. Riley Dept E241, Bldg 106

Martin Marietta Corp.
Mail Point 159 P.O. Box 5837
Orlando, FL 32855
Attn: F. Malatesta

General Dynamics
Pomona, CA 91766
Attn: J. Stamper

Boeing Aerospace Company
PO Box 3999
Seattle, WA
Attn: E. Wilhelm

Vought Corporation
PO Box 225907
Dallas, TX 75265
Attn: J. Craddock

Distribution (Cont'd)

Northrup Corporation
500 East Orangethorpe
Anaheim, CA 92801
Attn: Code &20 (R. Lawther)

Raytheon Corporation
Missile Systems Division
Hartwell Road
Bedford, MA 10730
Attn: T. Cullinane

Hughes Aircraft Co.
Missile Systems Group
8433 Fallbrook Ave
Canoga Park, CA
Attn: Mr. Buhnan
Bldg CT-10
Mail Stop T94

Defense Technical Information Center (2)
Cameron Station
Alexandria, VA 22314